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ABSTRACT

This manual adapts the pedagogy used on the playing field, the studio, and the stage to the classroom. This method, called "Pep Talk," encourages teachers to: (1) create a need to know; (2) challenge students to know; (3) show how to know; (4) apply know-how; and (5) know how to inspire cooperation. Pep talk is the method coaches use when they cheer their players to step up to the plate and swing at the ball, to play by the game plan, and to practice, practice, practice! Putting "Pep Talk" into action in the science classroom will: (1) involve students in doing science; (2) encourage students to risk developing their own ideas; (3) create a "can-do" attitude; (4) show the significance of science to daily life; and (5) communicate that it's okay to have fun. This philosophy is a backbone of a program called Real-World Science, which uses the type of curriculum found in this book. Real-World Science as founded in 1984 as a summer enrichment program for the purpose of building interest and confidence in science, strengthening the cooperation between industry and academia, and giving schools innovative ways to develop talent. Most of all, the program was designed to be fun. Scince its founding, over 350 students have participated in this new experiment in learning, along with their teachers who have been trained to teach real-world science in the classroom. This manual is divided into "Pep Talk," "Play Book," and "It's Your Turn." "Pep Talk" is the pedagogy and "Play Book" is the curriculum for teaching real-world problem solving to students. The chapters of "Play Book" describe the way scientists search for solutions by recognizing patterns, asking the right questions, making predictions with confidence, and doing experiments. Each of the chapters is organized according to the five basic rules of Pep Talk: create a need to know, challenge to know, show how to know, apply know-how, and know how to inspire cooperation. "Pep Talk" encourages teachers to coach students a little; let them play a lot. The third section ("It's Your Turn") gives teachers the tools to create a curriculum for their students based on a model curriculum presented in the "Play Book" section. Using the rules offered by "Pep Talk" a new curriculum can be created (or an existing one can be revised) that will give teachers an alternative way to teach science in the classroom. Appended are a list of resource materials, and a computer program (written in Basic) to compute a correlation coefficient. A bibliography of 100 references is included. (CW)

coaching science stars

Pep Talk and Play Book for Real-World Problem Solving

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coaching science stars

Pep Talk and Play Book for Real-World Problem Solving

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Tucson, Arizona

Coaching Science Stars
Grades 7-12

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To Dawn, whose pep talk kept this project alive.

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And to those teachers who recognize that "how to know" is as valuable as "what to know," thank you for helping change the way we teach.

Introduction

Imagine giving youngsters a lecture and a book on basketball and asking them to learn the necessary skills of the game for a graded quiz. How much enthusiasm for basketball would you create? Little, no doubt. But this same technique is used over and over again to teach science in today's classrooms. To expect students to be motivated to study science by this approach is just as shortsighted as it would be to assume they could use it to learn how to shoot baskets, play the piano, or act on stage.

The return of Halley's Comet rekindled excitement and public interest in science. The need to understand comet trajectories, supercooled gases, and orbital motion underscored the importance of quality science education. But while the comet sped by, surveys and studies revealed disturbing news about the success of our science education and the future of U.S. science endeavors: fewer and fewer students were motivated to study or pursue careers in science.

A good place to learn about motivation is a locker room, a music studio, or a stage. Athletic coaches, music teachers, and drama instructors know that study and discussion are not enough. They know that to be motivated, players and students have to become actively involved, try new experiences, feel a sense of achievement, and enjoy what they are doing. Shouldn't science teachers share the same approach?

Most schools have excellent sports, music, and drama programs to coach kids to play basketball, play an instrument, or act. Talented students are identified, given active coaching, and offered the opportunity to develop. Shouldn't similar programs exist for science and math? Although we meet the needs of sports and science stars differently, both thrive under good coaching.

Coaching Science Stars adapts the pedagogy used on the playing field, the studio, and the stage to the classroom. This method, which I call *pep talk*, encourages teachers to:

- **Create a need to know**
- **Challenge students to know**
- **Show how to know**
- **Apply know-how**
- **Know how to inspire cooperation**

Pep talk is the method coaches use when they cheer their players to step up to the plate and swing at the ball, to play by the game plan, and to practice, practice, practice! Putting pep talk into action in the science classroom will (1) involve students in doing science; (2) encourage students to risk developing their own ideas; (3) create a "can-do" attitude; (4) show the significance of science to daily life; and (5) communicate that it's okay to have fun.

Does pep talk work? Coaches look for enthusiasm, risk taking, mental preparation, and a desire to achieve. Together, these signal confidence. Research on learning shows that achievement and confidence are strongly related. If confidence is coachable, then achievement (whether in sports or science) is within the reach of anyone. The biggest payoff is that players enjoy what they are doing.

Having fun creates the motivation to repeat something and thereby establishes a pattern for future involvement. A youngster who shoots hoops after practice or seeks out more Hemingway stories has been stimulated to

be self-teaching. When this occurs, students share the joy their teachers and coaches find in their subject or sport.

Teachers, like coaches, thrill at the prospect of working with "natural talent." Children who are self-starters, natural risk-takers, and self-confident progress quickly. But working with students of average abilities can offer just as many rewards as working with the more talented. From the ability to motivate youngsters at every level to reach their potential, one can receive the satisfaction of knowing that every youngster can "star" in science.

This philosophy is the backbone of a program called Real-World Science, which uses the type of curriculum you will find in this book. Real-World Science was founded in 1984 as a summer enrichment program for the purpose of building interest and confidence in science, strenghtening the cooperation between industry and academia, and giving schools innovative ways to develop talent. Most of all, the program was designed to be fun. Since its founding, over 350 students have participated in this new experiment in learning, along with their teachers who have been trained to teach real-world science in the classroom.

Coaching Science Stars is divided into "Pep Talk," "Play Book," and "It's Your Turn." "Pep Talk" is the pedagogy and "Play Book" is the curriculum for teaching real-world problem solving to students. The chapters of "Play Book" describe the way scientists search for solutions by recognizing patterns, asking the right questions, making predictions with confidence, and doing experiments. Each of the chapters is organized according to the five basic rules of pep talk: create a need to know, challenge to know, show how to know, apply know-how, and know how to inspire cooperation. "Pep Talk" encourages teachers to coach students a little; let them play a lot.

The third section ("It's Your Turn") gives teachers the tools to create a curriculum for their students based on a model curriculum presented in the "Play Book" section. Using the rules offered by pep talk, a new curriculum can be created (or an existing one can be revised) that will give teachers an alternative way to teach science in the classroom.

Part One

PEP TALK

1 Pep Talk: Pedagogy for Real-World Problem Solving

Create a Need to Know: Invite Youngsters to Play

As part of a field trip to a robotics factory, students were hosted by a dynamic, knowledgeable engineer. Before the tour, he introduced the topic of robotics through two10–minute videos, followed by a 15–minute briefing of how the factory was organized. He was rudely interrupted by yawns and nodding heads as he was about to show the second video. The engineer was puzzled by why a seemingly motivated group of youngsters, given the opportunity to see the cutting edge of robotics firsthand, would respond with disinterest and boredom.

To find out why, contrast this experience with another field trip the same group took to a commercial fish farm for culturing trout. Upon arrival, the host (a former middle-school teacher) invited the students to walk around the facility and observe each operation in silence. When they regrouped, he asked the students to describe how they thought the culture operations worked. Each was eager to volunteer his or her impressions. The enthusiasm was contagious. During the second leg of the tour, questions came in machine-gun fashion. Fish farming continued to be the topic of discussion on the trip home and the next morning. Our host had created a "need to know" experience for students.

Your ability to create a need to know is your main asset for effective teaching. Teachers and coaches were interviewed separately to learn what qualities they considered important to nurture enthusiasm for learning. Here's what they said motivates:

What Coaches Said	What Teachers Said
Active involvement	Hands-on experience
Opportunity for fun	Enjoyment
Chance for new experiences	Being part of a treasure hunt
Opportunity for improvement	Chance to be successful
Time to be with others	The security of a group
Opportunity to be a winner	A sense of achievement

There is a pattern to the responses. Although they expressed it differently, both teachers and coaches identified involvement as the key to motivating youngsters. It doesn't matter whether the activity is sports, music, or science. Involvement, getting youngsters to play, creates a need to know. The difference between the field trip to the robotics factory and the visit to the fish farm was due to the magnitude of involvement. Interest in fish farming was piqued by first involving the novices physically and mentally in the culture operation. The robotics field trip would have inspired greater enthusiasm if a firsthand experience had been offered before the information on robotic technology was presented.

Research confirms what teachers and coaches already know intuitively. Studies tells us that we remember 10 percent of what we hear, 20 percent of what we read, and 90 percent of what we experience. Formal education for the most part ignores what intuition and research tells us about motivation. Reading and lecturing still account for over 80 percent of instructional time.

George Plimpton knows that experience is the best teacher. In order to describe the feelings of a marathon runner to his readers, George Plimpton signed up to run the Boston Marathon. This was his first attempt at participatory journalism, and it launched a writing career that produced *Paper Lion, Mad Ducks and Bears,* and *Open Net.* To gain insight about professional football, boxing, and hockey, Plimpton took up each sport as an amateur.

His insight into boxing was heightened by a ring encounter with champion Archie Moore. Looking up from the canvas through a bloodied eye gave Plimpton a view of boxing never written about before. His brief tenure as quarterback of the Detroit Lions led to a unique, realistic account of professional football. And his ability to write about hockey came as a result of fending the puck for the Boston Bruins.

George Plimpton is an ideal model for how to learn science. To become knowledgeable about a topic, first let experience become the teacher.

Challenge to Know: Swing at the Ball!

America's greatness was achieved by our willingness to pioneer new frontiers and ideas. A memorial to this spirit was the spaceship *Challenger*. The challenge of outer space has led to the design of space shuttles, orbiting satellites, and space stations to explore the universe. Enthusiasm for scientific ventures continues, despite the risks. For any single shuttle flight, the space agency estimates the risk of catastrophic failure in the fiery ascent to orbit at one in seventy-eight.

NASA's twenty-fifth mission, sending the *Challenger* into space, was planned for January 26, 1986. The seven astronauts ready to embark on a scientific exploration included a teacher, Christa McAuliffe. The explosion that killed all seven stunned the world. Many eulogies were written in their memory, including an especially poignant one by Mike Royko, syndicated columnist. "I've known so many people, and probably you have too, who have quietly slipped away after lives of frustration. People who never had a chance to climb the mountain of their souls. Or who had no mountains. The seven people on the spaceship, even the school teacher, had all chosen to climb. They wanted to walk the edge, with all the risks it involved."

Although still pained by the *Challenger* tragedy, American children are enthusiastic about the space program. Over 75 percent of young children who were surveyed said that they would like to travel in space. When parents, however, were asked the same question, few of them shared the enthusiasm of their children.

We are all born with that spirit of adventure, the urge to pioneer. To properly develop, it requires nourishment. Between childhood and adult life many of us lose that spirit. We take fewer risks. We stop swinging at the pitch. All youngsters need someone to challenge them, to bring out their best, whether it be through science, music, drama, or simply a puzzle.

Erno Rubik loves a challenge. One of the most successful games ever developed was Rubik's Cube. Behind its success is the challenge the game offers. It has been calculated that if every person on earth randomly twisted a cube once every second, about once every three centuries a cube would return to its original state.

Erno Rubik was a designer who built the cube because he liked playing with geometric figures. His room was filled with cardboard and wooden figures. He was intrigued by the challenge of how to move blocks in a cube independently without the cube falling apart. Using an engineering technique, Rubik built the blocks so that they held themselves together. During testing, he colored each side of a block a different color. As he turned the blocks randomly, he was fascinated by the parade of colors.

When Rubik decided to put the blocks back in their original configuration, he faced a bigger challenge. How to get home? As he twisted more, the colors became more scrambled. Rubik decided there must be a method to restore the original order, and he closeted himself in his bedroom to find the solution. A month later he emerged with the answer. Rubik speculated that the challenge would hook others as well. He was right. Over one hundred million of his puzzles have been sold.

Scientists love challenges. The following examples show how large a role *challenge* plays in science. Because of certain problems with rubber, Leo Baekeland, a chemist, created a new material, called "Bakelite," as a replacement. This synthetic polymer, the first of its kind, helped create the

plastics industry. The Incas, scientists discovered, were able to successfully perform blood transfusions when others had failed. Karl Landsteiner wondered why. His research revealed the different human blood groups, which led him to understand the possibility of how transfusions and organ transplants could be successful. Mathematician Alan Turing helped design a machine in World War II for the Allies to break secret codes. The new machine was the electronic computer. Now used in prescribing cancer chemotherapy and to predict prospects for oil, it has changed the way we live and work as well.

Students remember Christa McAuliffe as a pioneer who wanted to reach for the stars. As a teacher, Christa knew that children need mountains to climb and that a school should be a place that encourages risk taking. To most of us, learning a new skill, making a decision, or persisting after failure is just as risky as hang gliding or rock climbing. These kinds of risks can be experienced without the threat of physical harm through a game called Orienteering.

Orienteering takes place outside, in woods, fields, or schoolyards. The emphasis is on problem solving—one of the best ways to practice science. Players are given a compass and a map and taught the skills to use them. The objective is to locate "controls" placed at points along the course.

The essence of Orienteering is giving players choices. For example, players usually are given a variety of ways to reach a control. All route options involve some risk taking, such as deciding whether to take a long, safe route or a short, risky route through the forest, or, should a control be missed, deciding whether to backtrack or try a new route.

Participants might experience failures, but when they eventually find a solution on their own, they receive the satisfaction and develop the confidence of knowing that they can do it themselves. Games like Orienteering challenge your students to know. Cheer them to try again when they fail. You will be preparing them for leadership in the world outside the classroom.

Show How to Know: Give Students a Game Plan

Winning coaches know the value of a game plan. Coach Bear Bryant of Alabama had a plan for everything—plans for practices, for when his team was ahead or behind, and even for after the game. His foresight helped Bryant to become one of the winningest coaches in history. Other athletes also value game plans. Champions such as runner Carl Lewis and gymnast Mary Lou Retton visualize their performance days or weeks in advance, and they develop a strategy for a variety of weather conditions, playing fields, and competitors. Coaches constantly urge athletes to analyze past performances to see if a pattern underlies their losses and wins. From sound preparation, athletes develop a strategy that works.

The game plan scientists use is called the *scientific method.* The skills of observing, recognizing patterns, making and testing predictions, and interpreting results are used daily to solve problems in the sciences from astronomy to zoology. The method is not limited to traditional sciences. Others use it daily to conduct business, diagnose disease, and create new games.

Dr. Naismith had a plan for a new game. When Dr. James Naismith arrived on the campus of Springfield College in 1891, gymnastics was the only indoor sports activity available in the winter. The dean of the college

asked Naismith to develop an indoor game that would be fun and easy to play. He first tried modifying outdoor games for indoor use. Neither football, soccer, nor lacrosse worked inside. Each failure was discouraging.

Naismith then tried a different strategy. Instead of modifying existing games, he developed a plan for inventing a new one. He searched for a common denominator or pattern that made games successful. He discovered that a ball, teamwork, and a goal were components of popular games. He modeled a new game mentally, visualizing the movements of players and a ball. Goals would be placed at the ends of a court and the ball would be round. The goals could be elevated peach baskets, compelling the players to throw the ball in an arc. The game's rules numbered thirteen.

The day arrived to test the new game. Naismith promised his class that if the new game were a failure, there would be no further experiments. The tip-off between the two teams was the start of the first basketball game and the end of Naismith's struggle to motivate his students. Basketball was an instant success and is now played worldwide.

Plan to triumph. A triumph in science, as in sports, is a product of a good plan. The blueprints for our voyages to space were designed over eighty years ago when Henri Farman in 1908 coaxed an experimental airplane off the ground and set a world record for distance and time. He broke the record set four years earlier by the Wright brothers. However, neither Farman nor the Wright brothers understood how the plane flew. Until the work of Theodore von Karman, the correct thrust and lift were reached by trial and error.

The challenging task of explaining the mechanics of flight became the lifetime occupation of engineer von Karman. His application of fluidmechanics to the problem of wing design solved the puzzle of flight, equipping engineers with a plan for designing new flying machines. The zeppelin, supersonic airplanes, and solid-state rockets were a product of this plan. Aerodynamics was born, creating a future opportunity for interplanetary space travel.

The know-how to do science is already present in youngsters. Children naturally look for patterns, find a related problem to solve, and act out problems without being taught. This innate ability to solve problems can be seen when youngsters work to solve Minute Mysteries (Chapter 3).

If students are given a strategy of thinking they can use as a model, they clearly can improve their problem-solving skills. Inquiry skills, like the physical skills used in sports, music, or art, require constant nurturing. Coach kids in how to think. Give them a game plan to follow.

Apply Know-How: Practice for the Game

"What's the point?" students often ask in science classes. The question is a fair one. What is the significance of science? Research on learning shows that students really want to know how science affects their lives. The ability to relate science to the world outside the classroom, to apply the know-how

to solve problems in which they have an interest, is what keeps the motivation to learn alive after the initial resistance to learning is overcome.

If baseball players were required to practice skills for two years before playing a game, most would lose interest in the sport. Science students, like athletes, need to play the game frequently, to use the skills and information they have acquired, and to encounter a real need for more background and skills.

Sports gave this athlete the know-how to live. In high school, Jeff was a bust at both basketball and football. At the invitation of a coach, he tried out for wrestling. He was pinned in his first two matches. Most boys would have quit. But Jeff accepted the challenge to become better. In his senior year, he set his school record for matches won. This led to an invitation to try out for the 1980 Olympics. Jeff made the team, but because of the U.S. boycott of the games, Jeff's opportunity to compete was postponed. And then he discovered a lump. Jeff was diagnosed as having Hodgkin's disease.

Doctors told him to save his strength for the treatments. Most competitors would have immediately dropped their training plans. Having learned the importance of attitude through sports, Jeff never considered himself ill. He underwent radiation therapy and an operation to remove his spleen. He returned to practice two weeks later.

Jeff's last name is Blatnick. Most of us know the rest of his story. Four years later, Jeff Blatnick accepted the gold for the United States. During the awards ceremony, he endeared himself to a national audience when he dropped to his knees in prayer and cried in joy. This emotional outburst expressed his joy not only over victory on the mat but over cancer as well.

When Jeff gives inspirational messages to other cancer victims, he speaks from experience. No medicine can match what Jeff's Olympic victory did for many of them. During a June commencement exercise when Jeff was honored with a doctorate from his alma mater, he told the graduating seniors to have unshakable faith in themselves: "This is the spirit that is tough to test for but motivates you to do more than you thought you could."

Learn from real-world situations. The lessons sports teach about living is regarded highly by the most successful coaches. Head coach of the Penn State Nittany Lions, Joe Paterno, considers himself first an educator who encourages students to study as hard as they play. The pep talk pays off. The perennial power boasts one of the highest graduation rates for college football players. Paterno is as proud of his players who become dentists, teachers, and architects as the ones who go on to play for the pros.

Programs using the same pep talk Paterno uses can work in schools. The first Invention Convention in Massachusetts for elementary students was held on the campus of the birthplace of basketball. In the gymnasium, junior inventors waited their turns to show off their creations to a panel of judges. The excitement matched the pregame anxieties of a basketball game. Inventions from "slipless soap" to erasable labels for VCR tapes were evaluated for originality and practicality. At the recognition ceremony, the roar of the crowd's applause was just as loud as at the previous night's basketball game. The motivation students showed for solving real problems confirms the value of relating science to the world outside the classroom.

Other examples tell the same story. A program called Kinder-Economy teaches economics to children as young as five years old. Using scenarios that mimic the real world, students start companies whose businesses range from food to jewelry. The Future Problem Solving Bowl brings teenagers together to think about world problems. Students, for example, must come up with twenty problems the greenhouse effect might pose for the world. They debate their solutions against peers to compete at the state and national levels. And it is no surprise that year-round use of newspapers in classrooms can significantly increase student interest. Research shows that relating classroom lessons to world events not only improves motivation but benefits academic skills as well.

By changing the way we live, the accomplishments of inventors such as the Wright brothers, Thomas Edison, George Washington Carver, and others are everyday reminders of the value of real-world science. Credited with over a thousand patents, Thomas Edison revolutionized the way we communicate and entertain. But Edison's greatest invention was not the light bulb or the phonograph; it was the development laboratory. Edison

recognized the market for a product that didn't yet exist and found how to provide it. Because he didn't waste time on inventions that couldn't sell or that people didn't want, he became one of our most highly productive inventors.

Constructing models to solve real-world problems is the occupation of scientists, whatever the field—marine biology, psychology, or economics. The model may be a series of computer equations to predict future supply and demand or a profile of character traits that describe a certain personality type.

Making models of the world around us begins in childhood. From paper models that mimic airplanes to games that simulate economic practices (Monopoly), learning situations are abundantly available to children. Keeping their excitement and motivation alive requires constant practice. Help students see the point of learning. Get them to apply the know-how.

Know How to Inspire Cooperation: Baseball Is a Team Sport

Coaches come to practice dressed for action. They wear sneakers and carry whistles around their necks. Discussions, they know, are not enough to expect players to reach their goals. Coaches must show players how to shoot a lay-up, steal a base, or play as a team. The good coach shows by example, rather than tells his or her player how it should be done. Those who learn how to lead by example will have a positive impact on education, business, sports, and other areas.

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Christa McAuliffe led by example. Wow! A lesson in space. This ultimate in field trips would include a tour of the space shuttle, an interview with the astronaut team, and a discussion of the value of space travel. By choosing to become the first teacher-astronaut, Christa McAuliffe became part of the solution for recapturing the importance of education. Christa had a history of involving her class and herself in the lesson. She invited body builders, hairdressers, and others to visit her classroom. She took her class on field trips, conducted mock trials, and participated with them in many different activities.

She was chosen from eleven thousand schoolteacher-applicants. In her application to NASA, she wrote that her selection would symbolize not only the importance of teaching, but also the increasing role women are taking in science and technology. She would become a role model not only for students, but for women aspiring to take part in space explorations as well.

Christa traded her social studies classroom for a space simulator at Johnson Space Center. The next year included training in space simulators, physical conditioning on a treadmill, and classroom lessons in space technology. This was all preparation for her return to the classroom where she would share her experiences with students. Christa commented that "kids had a wonderful way of bringing you back to reality." And Christa had a wonderful way of bringing reality to kids.

Good teachers, like successful coaches, teach by example. Music teachers often play along with their students, reading teachers read aloud to their students, and science teachers demonstrate laboratory skills. Like good coaches, good teachers observe, evaluate, and diagnose. They work with students individually to sharpen skills. In view of the way science is practiced in the real world, teaching students how to play as a team is just as necessary as teaching basic skills. Learning how to solve problems together is important preparation for the world outside the classroom.

Use teamwork. Commercials showed Lee Iacocca, the president of Chrysler Corporation, in shirt sleeves, surrounded by factory workers. Iacocca came to the nearly bankrupt company dressed for action. Chrys-

ler's problems, according to Iacocca, were people problems. There was no teamwork, only a collection of independent players who had no common goals. Iacocca knew that if he could get people to realize that cooperation was key to Chrysler's survival, they could move mountains. Now a legend, the story of how Iacocca organized Chrysler's workers into a team to bring the organization back from the brink has become the American success story.

Scientists, like athletes and corporate managers, know the importance of teamwork. Even Thomas Edison knew the value of cooperation. Edison is often thought of as working alone at a lab bench, but this image is far from the truth. Edison invented with a team of scientists. One of his talents and insights, in fact, was that he could accomplish so much more through teamwork. He compensated for his difficulty with math and lack of skill with his hands by inviting people with minds for math and manual dexterity to be part of his team. Edison pioneered team research, employing up to one hundred scientists at a time to work on new ideas. At his death, he left behind more than 3.5 million pages of notebooks and letters, much of them documenting the experimentation that led to 1,093 patents. No individual could have achieved so much without the help of others.

The value of teamwork to science is well known today. A survey of recent inventions from robots that perform brain surgery to artificial bones revealed that the innovations were always a product of team research. Teams of scientists, often numbering in the thousands, are now working on space stations, a cure for cancer, and advanced computer chips. Drawing on each other's talents, scientists are accomplishing tasks they could never do alone.

Even though teamwork is common in our society, there is little emphasis on group work in schools. But changes are being made. Beginning with preschool materials, curricula that are child (instead of subject) centered are being tested in schools. From twenty-seven studies of collaborative learning, nineteen have shown positive effects. Working together, students learn as much or more as they do in conventional classes, feel good about themselves, and have a better attitude about learning. Long-term studies done by researchers from the Johns Hopkins University found that when it came to improving human relations, telling teachers how to do it didn't

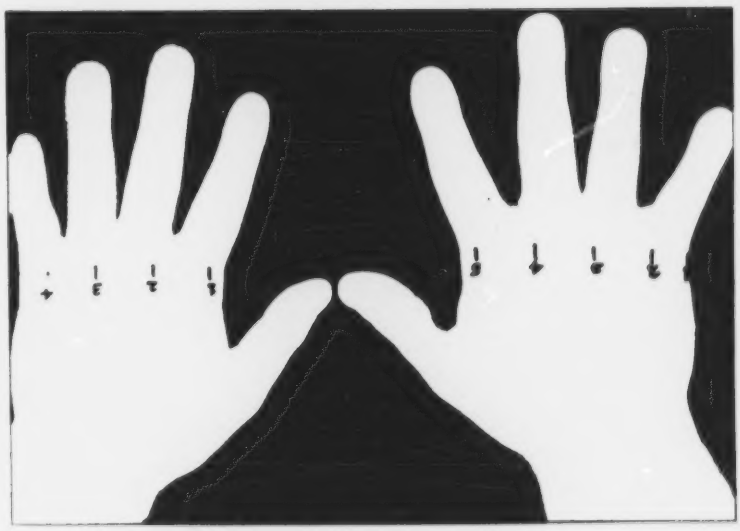
make much difference. Only when classes became laboratories in collaborative learning did race relations improve.

The best way to teach students the value of cooperation is by creating a need for it. Picture eight tree stumps separated by a distance too far for most people to jump. A group whose objective is to place each of its eight members on separate stumps begins at one stump. The group may use a plank that is long enough to just bridge the distance between two stumps. If either the plank or a person touches the ground, the group must start over. The time it takes to achieve the goal is recorded. This not only challenges participants physically and mentally, but requires that the group work cooperatively. Participants must plan each move together, weighing the distance between the stumps and the size of each person. To succeed, they must learn to share their ideas through brainstorming, listening to each other's ideas, and encouraging each other when they fail. Successful groups exclaim proudly, "We did it!" emphasizing the importance of "we" over "I."

Invite your students to be part of the solution. Coach them to solve problems as a team. Communicate that it's okay to have fun!

Part Two

PLAY BOOK



2 Learn to Recognize Patterns

What often separates scientists from nonscientists is the ability to see patterns. Patterns are observations that are organized into meaningful information to the observer. Believing that patterns underlie the structure of the world, scientists investigate with the confidence that the world will somehow make sense. Recognizing patterns is also important in fields other than science. A business manager looks for buying patterns, and a psychologist learns to recognize behavioral patterns. Artists are inspired by patterns in nature, and educators study patterns of student performance.

The all-time master of patterns does it as a hobby. Using only a pair of binoculars, amateur astronomer George Alcock has recorded four new stars (only three hundred have been recorded) and four new comets (only six hundred are known) from learning to recognize new patterns. Through planned and patient observations, the skill of recognizing patterns can be learned by anyone. This chapter presents creative activities for developing confidence in this critical thinking skill.

Skills	Activities	Materials
Developing pattern skills Applying pattern skills to problem solving	Makers and Breakers A Nature-Nurture Mystery	World Map Periodic chart of the elements Tape measures (cloth or plastic) Jar tops of various sizes Pocket mirrors

Students best learn about patterns through familiar examples and through their own experiences. Baseball, for example, is a game of hitting, fielding, and running. But the choices of what to hit and when to run are rarely left up to the players. Coaches at first and third bases give the orders. They rub their stomachs, touch their caps, kick the dust, then repeat the motions. This may all appear as nervousness, but in fact the coaches are signaling the players what to do. Their actions have a secret pattern, and if it is understood and followed by the players, the game might just be won.

The game of Makers and Breakers, described in the next section, is a fun way to practice pattern recognition using the scientific method. As with baseball, the players who are alert to patterns will be most successful. This game is a good introduction to Human Handedness, in which the patterns learned through game playing are practiced with people. Using themselves as subjects, students make observations of human laterality, from favorite side of the brain to dominant foot. The discovery of patterns from their own data helps students recognize the basic nature of laterality.

Through learning firsthand about laterality, students question its cause and learn about the nature-nurture mystery. Information from art history to family pedigrees is researched for clues to the cause of this behavior. After weighing the evidence, students decide on the cause(s) of laterality for themselves. The search for solutions to the nature-nurture question reinforces the importance of recognizing patterns from the observations students make and the data they gather. Students are encouraged to make the solution to this nature-nurture mystery the starting place for their own investigation of human behavior.

Throughout this unit, *Coaching Science Stars* adapts the pedagogy used successfully by coaches from sports to drama. Offer insight through involvement, challenge the student with a real problem, offer a plan of action, and let the student be part of the solution. Coach students a little; let them play a lot! With good coaching, every student can star in science.

Makers and Breakers

Goal. To help participants recognize patterns in the world and to reinforce the strategy of pattern recognition through a group problem-solving activity.

Prop. World map.

Introduction. What often separates scientists from nonscientists is the ability to see patterns no one else sees. For example, how many people who have studied a map of the world have noticed that the continents fit together like pieces of a puzzle? The discovery of the process of continental drift resulted from recognizing that the world's continents are like a giant jigsaw puzzle (demonstrate with a world map).

At some time during our Earth's history, the continents were joined together in a giant land mass, later to drift apart. As a result, continents now separated by thousands of miles contain many of the same fossils. The discovery of continental drift helped answer questions such as these: How could fossils native to China and Japan have gotten into the mountains of California? What are fossils native to our east coast doing on the west coasts of Europe and Africa? The distribution of the world's fossils forms a pattern described as a "common feature"; that is, despite being separated by space and time, objects or organisms share a common characteristic.

Overview. Makers and Breakers is designed to improve students' skills of pattern recognition. A small group of students, designated Makers, creates a pattern for others to break. The pattern must be a common feature designed from something physical that students can see. For example, all Makers could be wearing glasses or rings or could be holding their hands in the same position. The more subtle the pattern, the harder it becomes to break.

The rules.

- Divide the class into groups of at least three or four students each. Two groups will work together. Assign one group to be the Makers and assign the other to be the Breakers. Each group will take turns being Makers and Breakers.
- The Makers are challenged to design a pattern that illustrates a common feature. Allow about ten to fifteen minutes to create a pattern.
- The game starts when the Breakers try to break the other group's pattern. Makers can answer only yes or no to questions raised by the Breakers.
- Record the time it takes to break each pattern. Set a stopping time (for example, five minutes) if the pattern cannot be broken.
- Change groups, and repeat the game. The Makers with the most time are the winners.

Coaching hints. This game takes about an hour; allow about fifteen minutes for introducing the game, about half an hour for the game, and about fifteen minutes for processing the game. When groups are brainstorming patterns, walk around the room offering advice to groups that are having problems. Be careful not to intervene in groups that are doing fine on their own. The more times students repeat this activity, the more creative they become with making and breaking patterns.

After playing the game, the following questions can be used with students to process Makers and Breakers.

- Was the activity challenging?
- What was it like (degree of risk) for the first person in the group to propose an idea?
- What plan (of action) did each group follow to make or break a pattern?
- How was an agreement reached (teamwork?) about the proposed solution?

Real-world examples. To help students see the connection between their activities and the world outside the classroom, practice transferring the skills of pattern recognition to chemistry, biology, geology, or other areas of science.

Chemistry: A pattern illustrating a common feature in chemistry appears in the description of elements in the periodic table. Study the table with your class and try to identify some of its patterns. For example, each square contains information about the element's number of protons and electrons, chemical symbol, and atomic number. Every column contains a group of elements with similar properties.

Biology: The classification of organisms into *taxa*, or categories, is based on common features. Find a classification of primates in a text and ask students to identify the traits common to monkeys, apes, and humans. Ask students to compare the bones of the front fins of fish, wings of birds, and human arms. What bones do these vertebrates have in common?

Earth science: Invite students to describe the physical and chemical features the oceans have in common. What geological features do Acapulco (Mexico), Anchorage (Alaska), and Santiago (Chile) share? (Answer: these are areas of frequent earthquakes.) What features do Mt. St. Helens (Washington), Iraziu (Costa Rica), and Sangay (Ecuador) share? (Answer: these are areas of active volcanoes.) Ask students to compare marble, slate, and quartzite. What property do they have in common? (Answer: they all are metamorphic rock types.)

Mathematics: Give students jar tops of different sizes. Measure the circumferences and place the figures in one column. Next to this column, make another column listing the diameters. Divide the circumferences by the diameters. What common number results from the calculations? This was how the value of pi was first discovered.

Research: Articles that describe discoveries made in science are excellent real-world examples of the relationship of patterns to scientific discoveries. Assign articles describing discoveries from popular periodicals such as the *New York Times* (science section), or *Discovery* for students to read. Ask them to find examples of patterns that underlay discoveries described in these articles.

Careers: The task of many professionals besides scientists is to be alert for patterns. Discuss how pattern recognition is important to the careers of business managers, psychologists, educators, artists, detectives, engineers, and epidemiologists.

Create a Need to Know: Human Handedness

Which side do you favor? Ask students to write their name or shake hands with the hand they don't usually use. The awkwardness of using the opposite hand helps students become aware of the role *laterality* plays in human performance. Favoring either the right or left part of the body demonstrates laterality. In the following exercises, students test themselves for laterality, recording their responses to questions about how they perform routine activities. Favoring neither right nor left illustrates symmetry (two-sidedness) of human performance.

Hands: Ask students to record either "right" or "left" or "both" to these questions about their favored hand.

With which hand do you:

- ☞ write or draw?
- ☞ hold a hammer?
- ☞ brush your teeth?
- ☞ cut with scissors?
- ☞ wave good-bye?

If four or more of these activities are done with the same hand, this is the favorite hand. If only three of the five functions are done with the same hand, neither hand is favored.

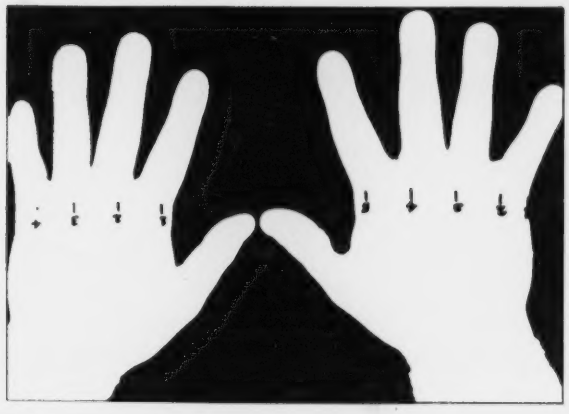


Figure 2.1. *Continuous use of the favored hand causes it to become larger than the one used less often. These are the hands of a track-and-field athlete who participated in the shot put, javelin, and discus events. The circumference of the right hand is almost one inch larger than the left.*

Some students may want to test how continuous use changes their own hand size. Give students a piece of string about eight inches long to measure the fist circumference of each hand. Instruct them to close the fist over the length of string and draw it tightly over the knuckles nearest the wrist until the string encircles the fist. Have students measure the amount of string used to go around the wrist by laying the string on a metric ruler. Record measurements to the nearest 0.5 mm for both hands. The hand favored to perform most activities is usually larger.

Eyes: Which eye do students favor? Tell them to focus (with both eyes open) on an object, such as a clock or a light switch, that is located six to ten feet away. State: "Stretch either arm in front of you and place your index finger between your eyes and the object. Close the left eye and open the right one. Then, close the right eye and open the left one. The finger will appear to move away from the object when one of the eyes opens. The eye that perceives **no** motion is the dominant eye. This is likely to be the eye you favor to look through a microscope or to wink."

Direction: Instruct students to sketch a dog or a horse on a piece of paper. Have them note the direction the animal is facing. This is the student's favorite direction and should be recorded as such.

Figure 2.2. *The direction the horse points is usually opposite the favorite hand. Right-handers, for example, usually point the head toward the left.*

Leg, thumb, arm, and ear: Ask these questions to help students learn which leg, thumb, arm, and ear are favored. Each response to this part of the self-test should be recorded:

- ☞ Which leg do you favor for kicking a ball? Examine the bottom of your shoes. Is the shoe with the greatest wear on your favorite leg?
- ☞ Fold your hands and interlock your thumbs. Which thumb do you favor to be on top?
- ☞ Cross your arms in front of you. Which arm is outside? This is your favorite arm.
- ☞ If you heard a strange noise directly behind you, to which side would you turn your head? This identifies your favorite ear. Is it the same ear to which you place a telephone receiver?

Side of face: Psychologists have recently reported that humans express emotions more intensely on one side of their face than on the other. Have students discover which side expresses happiness more intensely by studying the happy expressions in Figure 2.3.

Figure 2.3. *The photo on the left was created by splitting the full face of the original photograph down the middle and joining the two right sides. The original photo is in the center. The photo on the right was created by splitting the full face of the original photograph down the middle and joining the two left sides.*

The side of the face that expresses happiness more intensely than the other is the side favored by this person to express the emotion of happiness. Psychologists call this side the "public side" of the human face; the side that expresses emotions less intensely is called the "private side."

Have students repeat the test using photographs of themselves that express happiness. Tell them to place the edge of a small mirror on the midline of the face with the mirrored side toward the right side. Instruct them to look at the face created by the mirrored image of the right side and compare it to the full face. Then have them face the mirror toward the left side and compare the mirrored image of the left side to the full face. Which side is their favorite? Have them record their favorite or public side.

Side of brain: The laterality surveyed so far by students continues inside the body. For example, individuals may favor one side of the brain. The brain is divided by a longitudinal furrow into the right and left cerebral hemispheres. Each hemisphere is further divided into four lobes: frontal, parietal, temporal, and occipital. For over a century, researchers have looked for differences in structure between the two hemispheres. Until recently, measurements were done on brains removed from humans after death. By using the newly developed CAT (computerized axial tomographic) scanner, brains of living persons can be photographed for study.

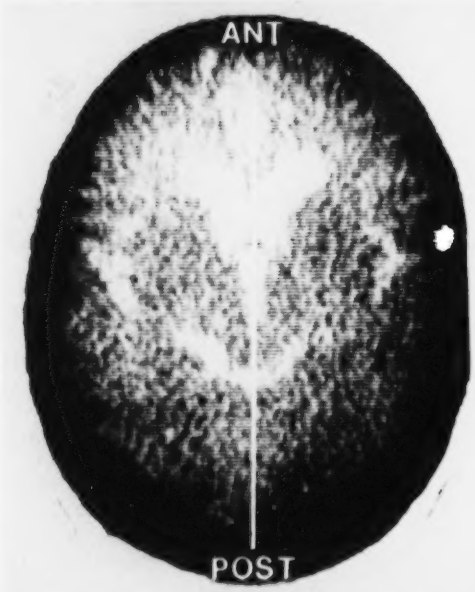


Figure 2.4. *The right and left cerebral hemispheres are divided along the brain's midline by a longitudinal furrow (marked by the white line). The left side of this brain is larger than the right side, illustrating that the brain is asymmetrical.*

Asymmetry of brain structure is believed to be related to handedness. Brains of right-handers studied so far are asymmetrical; the subject whose brain is featured in Figure 2.4 is right-handed. Like other bones, the skull adapts to unequal forces exerted upon it. The inner surface of the skull of right-handers is indented where oversized lobes meet the skull. Brains of left-handers are nearly symmetrical; valleys in the surfaces of their skulls are not common. This information could be used by anthropologists or medical detectives to learn the handedness of a person from only his skull.

Blau Torque Test. A simple written test, the Blau Torque Test, devised by psychologist Theodore Blau, will help students determine which side of their brain controls handedness. Ask students to draw two circles, one with each hand, on a piece of paper. Have them record with an arrow whether the circles were drawn clockwise or counterclockwise. Ask them to sign their names with each hand under the circles.

The strength and control of writing shown by the signatures is an indicator of the preferred hand; the circles are a test of cerebral dominance. Have students compare the direction of their circles to those of Figure 2.5. Determine which side of the brain controls their own handedness. Ask students to record this information.

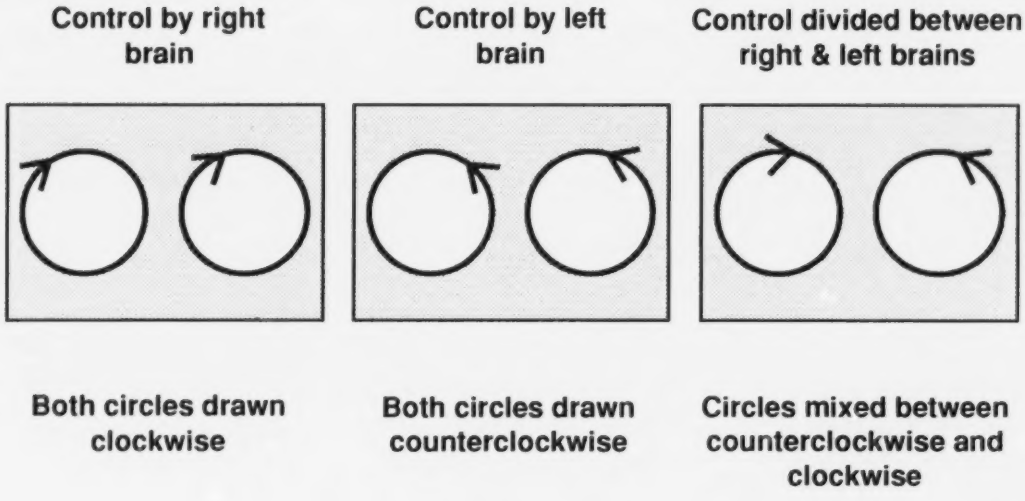

Control by right brain
Control by left brain
Control divided between right & left brains
Both circles drawn clockwise
Both circles drawn counterclockwise
Circles mixed between counterclockwise and clockwise

Figure 2.5.

Invisible as well as visible differences exist between left and right cerebral hemispheres. Brain centers that control human performances also appear to be lateralized. Experiments provide proof. While people were singing, narcotics were injected into the blood supply to the left and right brains. The illustrations in Figure 2.6 recreate the results of the experiment.

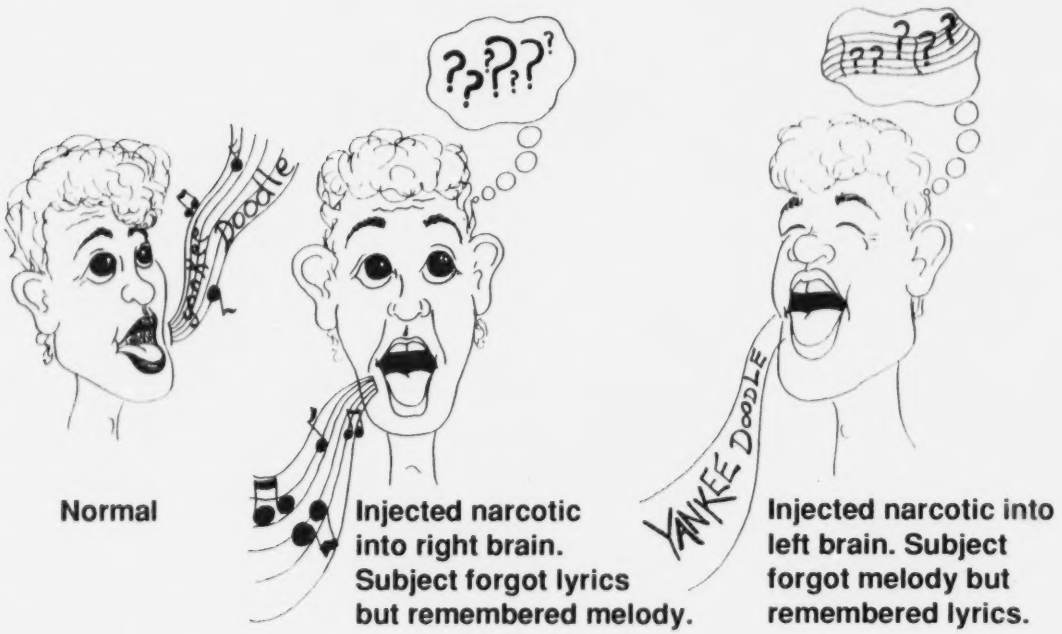

Yankee Doodle
??????
Yankee Doodle
??????
Normal
Injected narcotic into right brain. Subject forgot lyrics but remembered melody.
Injected narcotic into left brain. Subject forgot melody but remembered lyrics.

Figure 2.6.

Ask students how these results support the view that a music center on one side of the brain remembers the melody and a speech center on the other side remembers the lyrics of a song. Centers for the control of handedness, speech, calculations, language, spatial construction, and other skills seem to be localized in particular lobes. The centers for handedness and language are believed to be located together, in or near the temporal lobes. The curious fact about these centers is that they often exert their control on the side of the body opposite the side of the brain in which they are located. This is because nerves that "wire" lower parts of the body cross the body's midline before reaching the brain.

What patterns do you see? Shown in Figure 2.7 is a sample of laterality to which students can compare their self-tests. Your class results should be comparable to these. Note that the favorite side of the brain of most students is opposite the favorite hand. This pattern illustrates a change from the expected. What other patterns of laterality do you see? Ask students to use their data to identify the kinds of patterns learned through Makers and Breakers (for example, common features).

Part of body	Right	Left	Both
Hand	15	4	0
Eye	14	5	0
Direction	10	9	0
Leg	16	2	1
Thumb	11	8	0
Arm	11	8	0
Ear	13	6	0
Face	13	6	0
Brain	2	11	6

Figure 2.7. *Results of measuring the laterality of a class of nineteen students.*

Here are some patterns that might be extracted from such data:

- The majority of subjects are right-handed.
- If people are right-handed, they usually favor their right eye and their right leg.
- The side of the brain favored by most people is opposite their favorite hand.

Challenge to Know: A Nature-Nurture Mystery

Why do most humans favor their right hand? Interest in the cause of human handedness began centuries ago; we are still not certain what determines whether you will be right-handed or left-handed. Some believe that handedness is hereditary (a function of nature), favoring the idea that you are born with your favorite hand. Others think that handedness is learned (a function of nurture), believing that the family, school, and religious environments one experiences as a child influence handedness. Science calls the failure to find a solution to this question a nature-nurture mystery.

Risk your ideas. Brainstorm the cause of human handedness. Is it caused by nature or nurture or both? The cause of handedness is still uncertain because controlled heredity experiments cannot be done with humans (scientists cannot control who will father and mother the offspring). However, descriptive studies (similar to the one a prosecutor performs when he is missing the smoking gun) have been done. Circumstantial instead of direct evidence is used to prove guilt or innocence, as well as to promote theories about handedness.

What circumstantial evidence would you gather to prove nature or nurture? Follow these rules for brainstorming:

- **Say everything that comes to mind.**
- **Do not judge any ideas.**
- **Don't discuss anything.**
- **Repetition is okay.**
- **Piggybacking on others' ideas is encouraged.**
- **Accept and enjoy moments of silence; often a new burst of ideas follows.**

Show How to Know: A Plan for Action

Patterns of handedness can be found in the history of art, family pedigrees, school archives, foreign cultures, identical twin studies, and other resources. Students will gather clues from these sources, as well as from scientific reports and interviews with people from different countries. Students will be asked to weigh the evidence to estimate what part heredity plays and what part society plays in determining the favorite hand.

Clues from cultural patterns. No one has compared the influence of different cultures upon handedness. Are children in Europe, the Middle East, Brazil, Rhodesia, or Australia forced to use a particular hand, or are they permitted to choose their favorite? The answer is unknown. The family, school, and community are ideal places to begin an investigation.

Ask students to interview three people who have lived some or all of their lives in a foreign country. Students should start with their own families. Has one of their relatives lived in a foreign country? They should look next in their school. Do students from other countries attend your school as part of a foreign exchange program? Finally, students should look in their community. The yellow pages of the phone book list clubs of different ethnic groups. Suggest that they call one of these clubs and interview a member. The following summary of an interview with a husband and wife who grew up in the Chinese culture is an example of the type of information students might collect from "eyewitnesses." Reproduce the sample interview for each student, along with the page titled "Your Interview."

Sample Interview

Dr. Chun Wun was raised by Oriental parents. Dr. Wun recalls, "My family and I immigrated from Hong King to this country in 1966 when I was twenty-six. I was raised in a family that practiced traditional Chinese customs. Children were expected to hold and use chopsticks with only their right hand. If you forgot what hand to use, your father might rap your hand with a chopstick."

His wife, Eileen, taught grammar school for five years in the Hong Kong school system. Mrs. Wun says, "Chinese school children are also pressured by teachers to write with their right hands. The reason for this is hard to understand because it is difficult for right-handers to write Chinese. Chinese, unlike English, is written from right to left. When right-handers move their pen from right to left across the page, they often smudge their writing."

The Wuns' memories of life in China suggest that the handedness of the Chinese is strongly controlled by the training children receive in the schools and homes.

Your Interview

Begin by telling the person the purpose of the interview. Explain that they will be an eyewitness to help you solve the nature-nurture mystery. Use an informal conversation to conduct the interview. Record the replies to the questions.

Questions to Ask the Eyewitness of a Foreign Culture

1. *Does your country have any laws that pressure people to use their right hands?*
2. *Do churches of your country have any beliefs that pressure people to use their right hands?*
3. *Do communities of your country have any social rules that pressure people to use their right hands?*
4. *If you are talking to a person who is left-handed: Were you ever pressured by parents or teachers to switch to your right hand?*
5. If you are talking to a person who is right-handed: *Were you switched by parents or teachers from your left to your right hand?*
6. Ask the person to try to recall his or her first writing class: *Were your classmates pressured by teachers to write with their right hands?*

If the eyewitness answers yes to any of these questions, the environment of the school, home, or community had an influence on hand use. If the person answers yes to two or more questions, it is likely that their handedness is culturally determined.

A scale such as the one below may be used to record the results. If the evidence favors culture, circle a number on the nurture side. If the evidence favors heredity, circle a number on the nature side. If the facts favor both heredity and culture, circle numbers on both sides. The value of the number represents the strength of the evidence in favor of either nature or nurture; the higher the number, the stronger the evidence.

3 2 1 0 1 2 3

NATURE NURTURE

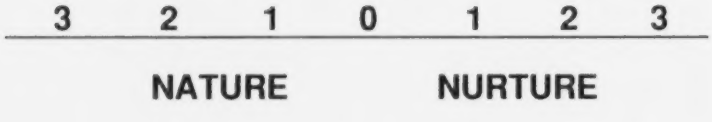
Clues from foreign exchanges. Do different cultures have different frequencies of handedness? Oriental children have a far lower frequency of left-handedness than Americans. Less than one percent of Oriental children hold chopsticks in their left hands; the percentage of American children who eat with their left hands is much higher (Figure 2.8). Is the frequency of left-handed Americans higher because Americans have more genes for left-handedness (nature)? Or is it higher because Americans are more tolerant of children who favor their left hand (nurture)?

	Left	Right
Native Oriental children (Taiwan)	0.7%	99.3%
Native American children (Berkeley, California)	9.9%	91.9%
Oriental-American children (moved with parents from Taiwan to Berkeley)	6.5%	93.5%

Figure 2.8. *Comparison of the handedness of children born and schooled in Taiwan, children born and schooled in Berkeley, California, and children born in Taiwan but schooled in Berkeley.*

Comparison of frequency of handedness. Two kinds of experiments could be done. Genes of Oriental and American children could be switched. This, for instance, might decrease left-handedness of Americans and cause left-handedness of Orientals to rise. The technology to switch genes exists, but no one, so far, has switched genes between humans.

In another kind of experiment, children of Oriental and American parents could be switched. Ask students: "What would happen if an Oriental student traded places with you? Would the student experience more pressure or less pressure from teachers to use the right hand?" Figure 2.8 reports what happened when Oriental children moved from Taiwan with their parents to live in Berkeley, California, and attend school in Berkeley. Their handedness was compared to that of native Taiwanese children and native American children. The frequency of left-handedness in the immigrants was lower than it was for native Americans but higher than for native Orientals. Ask students: *"What cause does this clue favor?"* Tell them to record either nature or nurture on the scale.



Ancient history patterns. The history of ancient cultures can be studied to find information about handedness. History tells us that no culture was permanent. Every culture, from the cave dwellers to the Roman Empire, declined and was replaced by another. Whenever human culture changed, did the ratio of right-handers to left-handers also change? If history shows that it did, determination of handedness is probably cultural. If the ratio has remained nearly the same, control of handedness is probably hereditary. (Human genes are very stable; for every million genes that are passed from parent to child, an average of only one gene changes.)

A written history of handedness has never been recorded. But a rich history of art, dating back at least fifty centuries, fortunately does exist. The handedness of past cultures can therefore be studied by examining art. The first artwork was produced nearly sixty thousand years ago. Recorded on stone cave walls are drawings of the animals that early man hunted. These cave drawings reveal by the direction the animals are pointing whether the artists were left- or right-handed. Ask students to assume that each animal in Figure 2.9 was drawn by a separate artist and to calculate the frequency of right-handedness of Stone-Age men. Record this frequency of handedness.

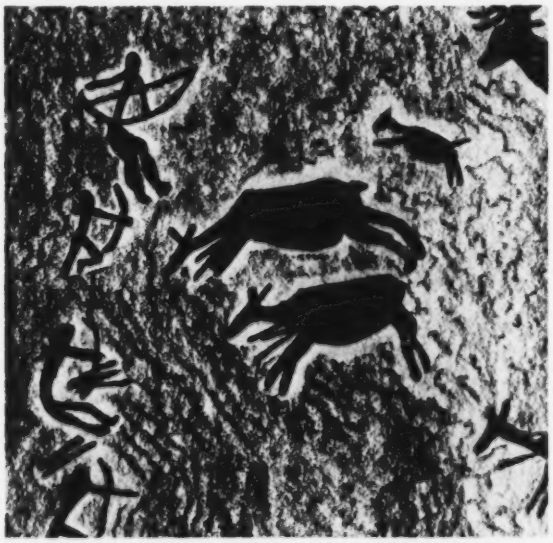


Figure 2.9. *A cave drawing can reveal, by the direction the animals point, the handedness of the artist.*

Still missing is information about handedness for the time between the Stone Age and the present. A written account of handedness appears in the New Testament, in Judges 20:15-16. This description estimates the handedness of nearly two thousand years ago. Tell students to find this figure in the Bible and record it .

Hanging on the walls of our art museums are clues to the handedness before and after the birth of Jesus. These masterpieces display a history of the world's major cultures that goes back perhaps fifty centuries. Because

art often depicts humans using their hands, the history of art offers a way of studying the history of handedness. Instruct students to research handedness using the following directions.

Searching for clues in art museums.

☞ Travel to the nearest art museum or, if travel is impossible, obtain a book of illustrations of art work through the ages.

☞ Locate the paintings in the museum (or described by the book) that were done in the cultural eras listed below. Paintings from other eras may be added if time permits.

Cultural Era	Time
Greek Culture	500 B.C.
Renaissance	A.D.1500
Nationalism	A.D.1800

☞ Study as many humans using their hands as possible. Accuracy improves by increasing the total number of samples. Calculate the percentage of right-handers for each era. Record these frequencies.

A word of caution: The clues given by art history should be interpreted cautiously. Artists sometimes drew subjects holding objects in their left hands to symbolize the devil or evil, regardless of whether or not the subject was left-handed. The symbolism sometimes present in art might therefore give a false impression of the frequency of left-handedness compared to right-handedness.

Instruct students to find today's frequency of right-handedness. The most up-to-date research laboratory is a first-grade classroom. Suggest that students request an elementary teacher to help them by counting the number of children in the class who write with their right hand and the number who write with their left. (Your own class can be substituted for the elementary class.) Tell students to record the figures. If the frequency of right-handedness has changed little through the ages, they should record nature as a cause. If the frequency changes greatly, they should record nurture as a cause.

3 2 1 0 1 2 3

NATURE NURTURE

Patterns from modern history. Current clues to the nature-nurture mystery can be found in twentieth-century American history. Handedness in the United States has been recorded in print and photographs. An unrecorded oral history also exists in the memories passed on by earlier generations. Both types of resources can be used to trace the modern history of handedness.

Because the hand a person uses to write or draw is the best index of favorite hand, classrooms can be searched for clues. Photographs have been taken of early writing and drawing classes. Figure 2.10 is a photograph of a first-year writing class taken in 1893, and Figure 2.11 shows a drawing class photographed twenty years later. Instruct students to count the number of left-handers in these classes and to record the percentages. Have them also count the number of left-handers in your class or another class and report this percentage.

Experts believe that the percentage of left-handers in America has risen since the turn of the century. One reason for the rise may be heredity. Another is culture. Some believe there are now more left-handers because American teachers and parents are more accepting of left-handers today.

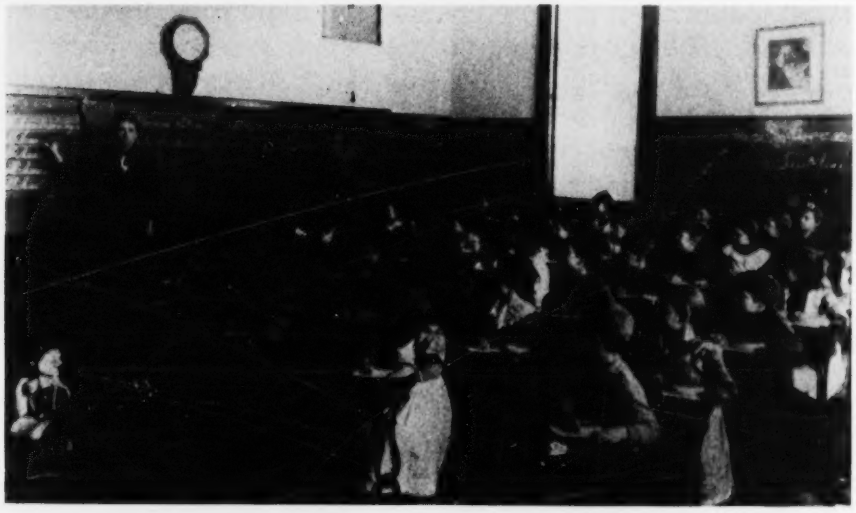


Figure 2.10. *How many lefties are in this first-year writing class of 1893? (Answer: none.)*

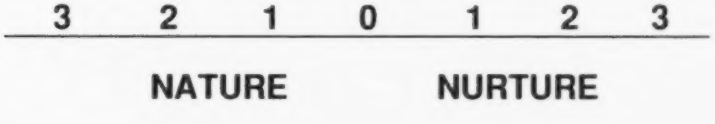
Figure 2.11. *How many lefties are there in this drawing class of 1913? (Answer: none.)*

Today, most teachers let students choose the hand they prefer to use to write. School psychologists point out that children who are forced to switch from left to right hand often become frustrated. Teachers are urged to help left-handers by teaching them to shift their writing paper toward instead of away from them. Physical educators now commonly teach physical skills for both right and left hands.

Use oral history to help students find the reason for the rise in left-handedness. Tell students to ask other teachers to help recall the history of tolerance of left-handers from the turn of the century to the present. Instruct students to use these two questions to interview teachers of varying ages.

- ☞ As a student, were you or your classmates pressured to write with your right hand?
- ☞ As a teacher, did you or other teachers pressure students to write with their right hand?

If left-handers were always tolerated by teachers, students should report nature as a cause. If left-handers were not always tolerated, report nurture as a cause.



Patterns from a family history. Family trees can help solve the nature-nurture mystery. Students can study their own (or someone else's) family history to help decide if handedness is hereditary. A family history or pedigree shows how a trait passes from parent to child.

Genetic counselors use pedigrees to describe the etiology of hereditary diseases and to tell parents the chances of the disease occurring in their children. Except for diseases or other traits that have been studied for a long time, it is not possible to prove that a human trait is hereditary, because neither the lineage nor the environment of a family can be controlled.

Instruct students to make a pedigree of their family using the symbols of Figure 2.12. Have them ask parents, grandparents, uncles, aunts, sisters, and brothers which hand they use to write and to eat, and then have them illustrate the hand favored by each on the pedigree. Instruct students to use the symbols for left-handed to illustrate people who are ambidexterous

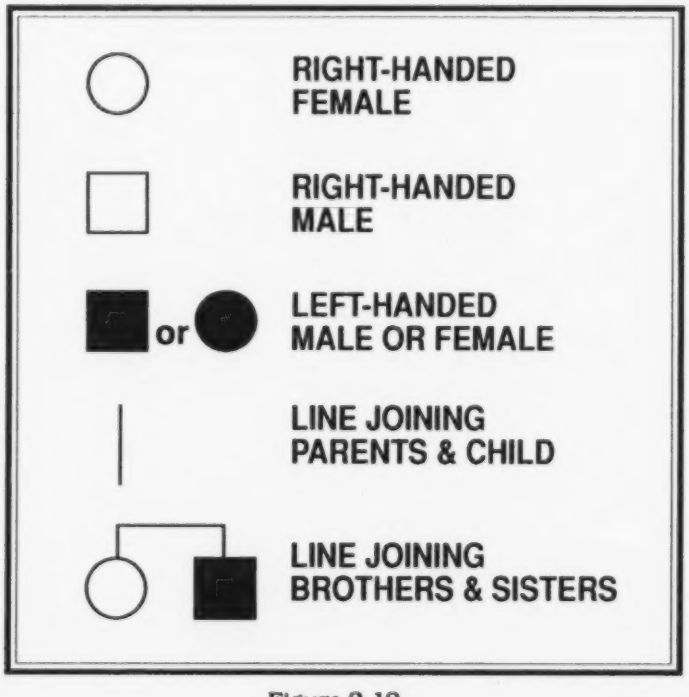


Figure 2.12.

Sample pedigrees for three generations of three unrelated families, illustrating the characteristic for blue eye color, are shown in Figure 2.13. Ask students to compare the three pedigrees. Because the trait is passed from parent to child or grandchild, the trait is hereditary.

If the students' pedigrees prove that the trait for right- or left-handedness is heredity, they should record heredity (nature) as the cause. If they do not find proof that this trait is inherited, they should record nurture as a cause.

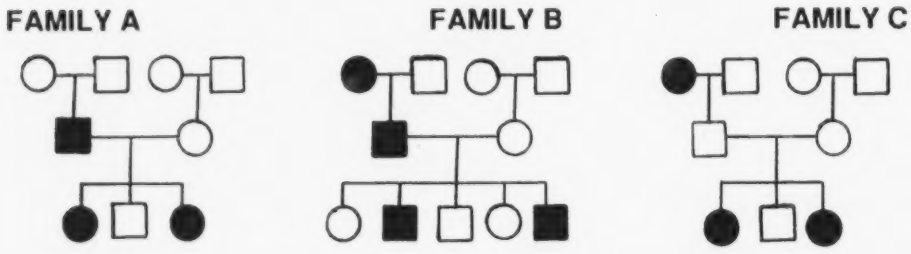
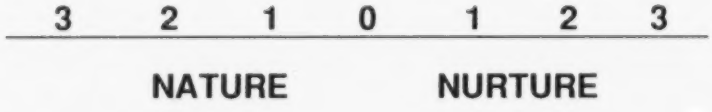


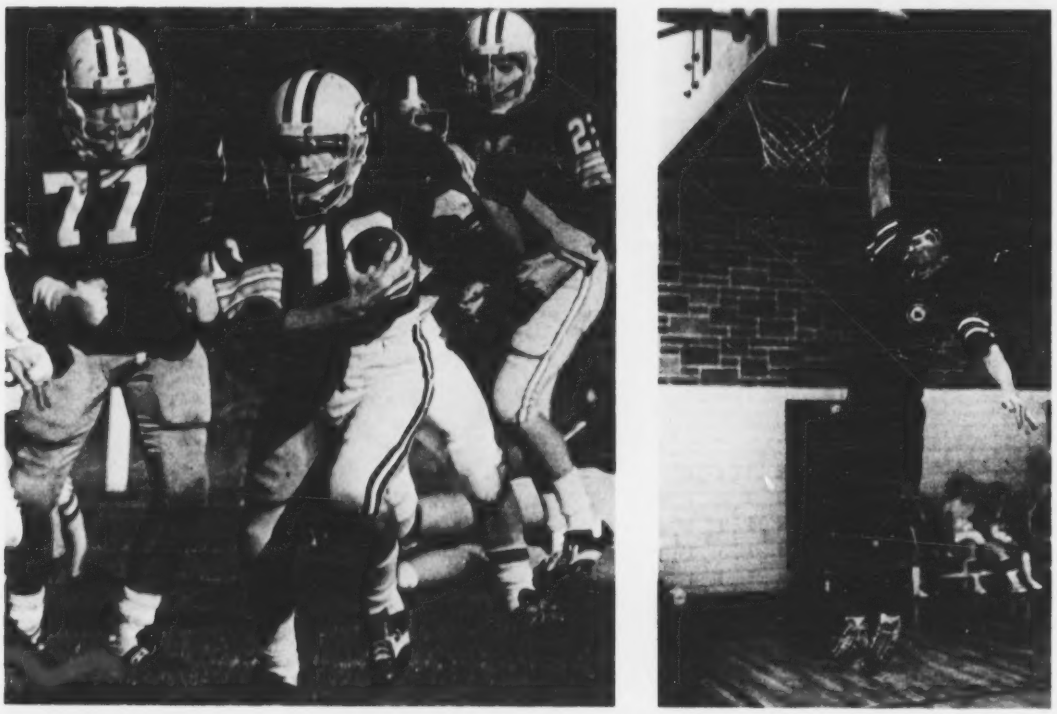
Figure 2.13. *A sample pedigree shows how the trait for blue eyes is passed from parent to child in three unrelated families. (Black circles or squares indicate blue eyes.) The pedigree of family C shows that blue eyes can be passed from grandparent to grandchild, skipping the parents.*



Patterns of identical twins. Clues to the cause of human handedness are offered by people who share exactly the same genes. Identical twins show similarities in their blood types, fingerprints, blood pressures, heart rates, and voices. Scientists have tried for a long time to prove that even their personalities are carbon copies of each other, and there is now some evidence that this is true. Twins separated at birth and reunited several years later have very similar personalities. When a pair of Ohio twins, for example, was reunited after a separation of thirty-nine years, it was discovered that both favored the same hobbies and even crossed their legs the same way.

The reason for the likeness is that identical twins start life together from the same fertilized egg. Sometime before the tenth day after fertilization, the egg separates into two eggs. Each egg receives exactly the same kind of genes as the other, so life begins for each twin with the same hereditary factors.

Do identical twins use the same hand? Figure 2.14 shows photographs of identical twins. These twins represent a few who agreed to help solve the great nature-nurture mystery. The handedness of the other twins whose pictures are not shown is reported in Figure 2.15. (Because identical twins are rare—only 3.5 are born per every 1,000 births—advertisements to find identical twins were placed in a newspaper.) Students should add the handedness of identical twins they know to the list.



Figures 2.14. *Tony and Mark are identical twins. Mark starred in football and Tony in basketball. Both athletes favor the same hand.*

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Identical Twin Pair Number	Both R	Both L	One R and One L
1		yes	
2	yes		
3	yes		
4	yes		
5			yes
6	yes		
7	yes		
8	yes		

Figure 2.15.

If control of handedness is hereditary, either both twins will be right-handed or both will be left-handed. If control is not hereditary, one twin may be right- and the other left-handed. If you think the evidence favors heredity, record nature as the cause. If you do not think the evidence favors heredity, record nurture.

3 2 1 0 1 2 3

NATURE NURTURE

Make a conclusion. The proposed solutions to the nature-nurture mystery are now tested. The solutions are further reminders of the importance of recognizing patterns. Divide students into groups of three or four students. Briefly introduce each clue (or possible cause of handedness) and ask groups to volunteer to follow up on the clue outside of class. Give each group a copy of the instructions for researching each clue.

Process this activity by asking each group to share its results and evaluate the clue it was assigned to research. Their research will often show evidence in favor of both nature and nurture. The scale below can be used to rank how strongly the clue favors nature or nurture.

3	2	1	0	1	2	3

NATURE **NURTURE**

A way to conclude the nature-nurture question is to list the rankings done for all the clues on the board. Add the numbers for each clue. Is one choice clearly favored?

Some questions to help process this exercise are:

- ☞ How did the skill of pattern recognition help you research the clue?
- ☞ What were your predictions and how were they tested?
- ☞ How were conclusions about this nature-nurture question reached?
- ☞ What are some real-world examples of other nature-nurture problems?

Apply Know-How: Other Nature-Nurture Mysteries

Handedness is just one of the many human behaviors, traits, or preferences whose cause is still a mystery. Scientists and others have long been interested in the roots of these behaviors. If a trait is determined by nature, perhaps genetic engineering could change it early in life. If it is determined by nurture, the condition could be changed by altering the environment at home, school, or work. Areas of research include which hand we favor, talents we have, our phobias, the sports in which we excel, the foods we prefer, the hobbies we enjoy, our habits (good and bad), diseases and allergies we suffer, and visual or hearing impairments.

Favoring one side is natural. Favoring one side (laterality) is the rule in humans; this is natural in other animals as well. Laterality is especially noticeable within the animal group crustacea—the lobsters, shrimp, and crabs. Not only do these animals display several different types of appendages, but paired appendages often differ in shape and function. The posterior limbs of male hermit crabs, for example, are entirely absent on one side, and the right claw of the first pair of claws of ghost shrimp and male fiddler crabs differ markedly in size. Snails are also asymmetrical. The shells of most snails coil to the right. This reserves less space for organs on the right, and as a result the right side of the pair of some organs may be missing. Even fish prefer one side. At metamorphosis, larval flounder give up their free-swimming existence to lie on the bottom. Some flounder species lie on their right sides and others lie on their left (Figure 2.16).

The exception to the rule. There are exceptions to the rule. Fiddlers with larger left than right claws, snails whose shells turn to the left, and flounder that lie on their left instead of their right side are occasionally discovered. The exception to the rule in humans is the left-hander.

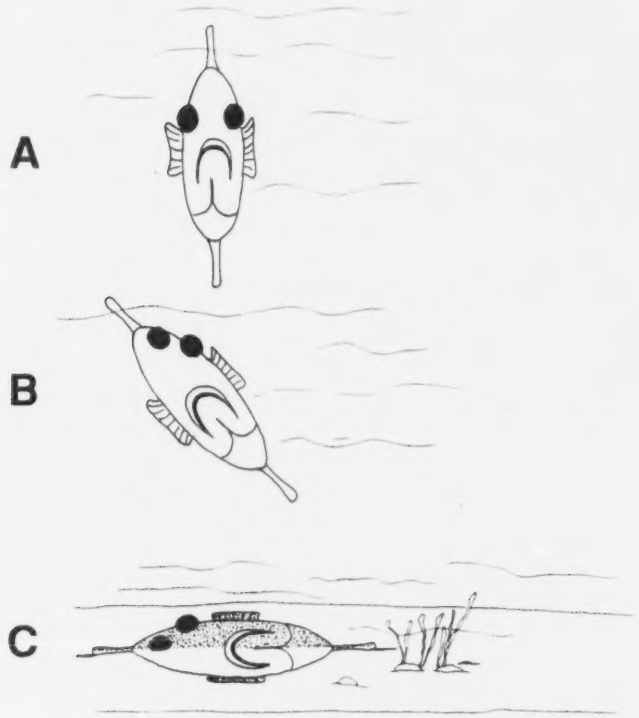

Figure 2.16.

A minority of Americans are left-handed. Ask students to estimate the frequency of left-handedness in your class or in a group of about twenty people and to record this frequency. These people often live with regulations designed for the majority. Ask students to look around the room and list items that were designed only for the right-hander. Suggest that they begin their list with the pencil sharpener and the notebook designed for right-handers.

The direction in which words are written (except for Hebrew and Oriental languages) favors the right-hander. By writing from left to right, the majority of us can pull our pen over the paper, preventing the tip from catching on the paper. Left-handed writers adjust by using one of two handwriting postures. Some write with "hooked hand," with the hand above the line of writing (Figure 2.17a). Others write with a common right-hand position, in which the hand lies below the line (Figure 2.17b).

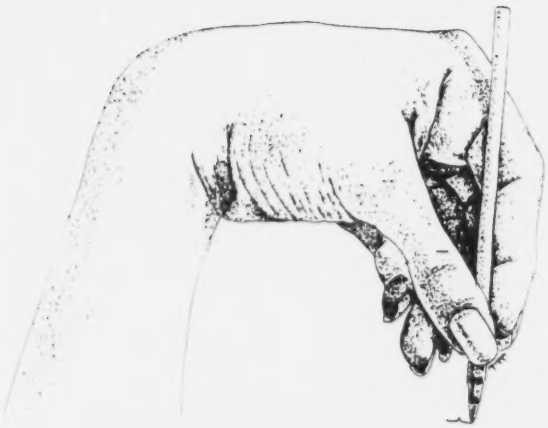

Figure 2.17a.

Figure 2.17b.

Rooted in the world's languages is further evidence that many cultures have discriminated against the lefty. Compare the English translations of right and left for three languages:

"Derecho," meaning "just," is Spanish for right.
"Izquierdo," meaning "deviate," is Spanish for left.
"Recht," or "correct," is German for right.
"Links," which means "awkward," is German for left.
"Retto," meaning "straight," is Italian for right.
"Sinistra," or "sinister," is Italian for left.

Certain figures of speech would lose their meaning if there were no discrimination against left. Who would want to be the boss's "left-hand" man, say "left on" to express agreement, or travel a public "left-of-way"? The designation of rebellious or radical political groups as "leftists" and conservative, steady groups as "rightists" is now a permanent part of our political language.

In a world seemingly made for right-handed people, people who are exceptions to the rule often experience during childhood frequent prodding from parents and teachers to perform basic skills with the right hand. Educating hands to perform specific skills is important in many cultures; in some Middle Eastern countries, the right hand is designated for eating from the communal dining bowl and the left hand for toilet activities. Citizens who lose their right hand through an accident are prevented from communal eating and become social outcasts. New information, however, has made Americans today more accepting of left-handers. Directions for knitting and other activities are now written for the left-handed, and left-handed scissors, baseball gloves, desks, and other articles are offered for sale. There is even an association of left-handed people (Left-handers International).

The relation between handedness and cerebral dominance would be relatively simple to see if there were no left-handers. Hemisphere dominance for about 40 percent of left-handers is the expected reverse of right-handers. Control in the remaining left-handers is either symmetrical (divided between the two hemispheres) or strongest on the left side. Researchers claim that the two different writing postures used by left-handers are simple clues to brain control. Control in left-handers whose hand lies below the line of writing is exerted by the brain's right side. Control in left-handers who hook their writing hand is exerted either by the left side of the brain or is divided between both sides.

Lefties are exceptional. Many left-handers are exceptional people as well as exceptions to the rule. Presidents Ford, Truman, and Garfield were left-handed. Tennis and baseball seem to favor the left-handed: Babe Ruth, Lou Gehrig, and Ted Williams were all left-handed, and lefties Jimmy Connors and John McEnroe have shared the spotlight in center court.

Creativity may be a feature of left-handers. Benjamin Franklin and Leonardo Da Vinci both worked left-handed to develop their inventions. Picasso's and Michelangelo's works of art were created left-handed. Art teachers today are experimenting with the idea that the left hand may be more related to creativity by encouraging their students to use their left hands. A recently discovered fact is that left-handers have a superior musical memory and music-processing ability. (Could this have contributed to the success of Judy Garland and Beatle Ringo Starr?)

Exceptional also about left-handers is that they form two populations — strongly and moderately left-handed. The latter seem to have fewer functional differences between their two hands than do the strongly left-handed. Symmetry of handedness is commonly referred to as "ambidexterity," the ability to use each hand equally well. Signatures written with the left and right hands, for instance, will show nearly equal control and strength. It is claimed that Michelangelo was ambidextrous. What an advantage to someone who painted ceilings for four years! Ambidexterity is advantageous in jobs requiring fine motor skills, from puppeteering to dentistry, and for adjusting to a world that is made largely for right-handers.

Know How To Inspire Cooperation: It's Their Turn

The nature-nurture question offers a number of interesting starting places for students' own investigations of human behavior. Ask students to choose one of the human behaviors listed previously or to brainstorm one of their own for study (the newspaper is a good resource for real-world examples).

Group students by behavioral interests. Suggest that they practice division of labor. Who will take leadership for organizing the study? Who will organize taking measurements? Who will record the data? Who will compute the data? Who will write the results? Who will organize a literature search?

Before starting, require groups to write a plan of action. Developing the right plan is the key to success. A plan that permits students to test their

predictions makes use of the scientific method. Ideas for how to plan a study can be borrowed from the nature-nurture section of "Human Handedness" in this chapter:

1. Make observations of the behavior.
2. Look for patterns or common features as well as changes from the expected.
3. Make predictions about the cause(s) of the behavior—nature, nuture, or both?
4. Test predictions by studying patterns of behavior in families, twins, history, etc.
5. Weigh the evidence for/against nature and nuture.

The plan of action, or research proposal, is submitted by the leader for your approval. Once you give approval, cheer students on to try it! Be available to offer advice and suggestions in the event of failure. Remember, it's their challenge. Coach them a little; let them play a lot.

3 Learn to Ask the Right Questions

Knowing the right question to ask is often the key to finding the solution. This talent is important to attorneys, physicians, and journalists as well as scientists. No one is born with this talent. It is learned through trial and error, just as you might learn to play a guitar or ride a bicycle.

To find the *Titanic* on the seafloor of the Atlantic, Robert Ballard, along with the explorers who tried before him, used trial and error. Using the same method, Watson and Crick constructed a working model of DNA, and Paul Ehrlich discovered a cure for syphilis. Ehrlich, for example, tested more than three thousand chemicals before identifying arsphenamine, an arsenic compound, as the first truly useful treatment for syphilis.

From the responses to a number of trials, a pattern appears. This pattern helps investigators choose the best solution. A physician, for example, asks an ailing patient a series of questions. From the responses, a description of the symptoms of one or more diseases emerges. By asking more questions, the physician narrows the possibilities before making a diagnosis about the cause of the ailment.

You can nurture the skill of framing the right question through a problem-solving activity called the Minute Mystery. Minute Mysteries not only develop important skills, but are fun to solve. Success may come slowly, but once students get the knack, they will ask for more and more mysteries to solve. Once students have confidence in learning how to ask the right question, this skill is put to work to solve a problem called Human Ecology, or What and Where to Build.

Skills	Activities	Materials
Developing questioning skills Applying questioning skills to problem solving	Minute Mysteries Human Ecology, or What and Where to Build	Toothpicks Used tennis balls, or anything available for building a model Drawing paper Rulers Protractors Knives (to cut building materials) Foamboard, cardboard, or balsa wood

Human Ecology addresses present and anticipated problems in land-use planning. The question of what type of habitat to build and where to site it cuts across the disciplines of ecology, conservation, architecture, law, and technology. The project begins by engaging students in designing a home of the future for living, working, or recreation. The nature of the design is guided by brainstorming appropriate questions to ask. The importance of recognizing future trends (patterns) in energy sources, water treatment, waste management, etc., is the key to asking the right questions about the habitat's design.

Where to site the home on the best of two or more pieces of real estate is the students' decision. An environmental impact analysis of the properties that raises the right questions about species diversity, diversity of habitats, wetlands protection, and endangered species guides students to making an intelligent decision about location.

Minute Mysteries

Goal. To show participants working as a team how to ask sound questions based on the patterns they see.

Introduction. This activity is designed for participants to solve short mysteries together. Participants learn to ask the right questions through trial and error. Good listening skills are as much a requirement for solving the mystery as good questioning skills. From the answers, a pattern is established that eventually leads to the solution of the mystery. Those who learn to look for a pattern (a change from the expected, common feature, etc.) will be the most successful.

The rules.

- Mysteries are solved by asking general, then more specific, questions. Only yes or no answers to questions may be given by the leader. Emphasize the fact that good listening and questioning skills are important.
- In view of the fact that this is a team effort, working together is particularly important to solving the mystery. Coach participants to stretch their thinking by looking for the unexpected, thinking in reverse, and questioning the obvious. Never give the answer. Be patient. Through persistence, students will eventually crack the mystery.
- This same kind of tenacity is required to solve scientific problems, particulary those that use a trial-and-error approach. The history of science provides many good examples. It took inventor Paul MacCready more than four hundred test flights, hundreds of crashes, thirty-five major designs, and thousands of small adjustments before he was sure his *Gossamer Condor* would become the first truly human-powered aircraft to sustain controlled flight.

The Mysteries

Who were the two men? *A man left home. He took three left turns and returned home. Two men were waiting for him. Who were the two men?* (Answer: The umpire and the catcher.)

The bar *A man goes into a bar and asks the bartender for a glass of water. The bartender pulls out a gun. The man says thank you and walks out of the bar. Why?* (Answer: The man had the hiccups.)

Emergency *A father and his son are in a car accident. The father dies. The son is rushed to the emergency room. The doctor comes into surgery and says, "I can't operate on this boy; he's my son." Explain.* (Answer: The doctor is the boy's mother.)

Bicycles *A man is found dead in a room with fifty-two bicycles in the room. Why was he killed?* (Answer: The bicycles were on the back of playing cards manufactured by Bicycle Company. Cheaters never win.)

Dead in the middle of the road *A man was driving down the road in his car with the windows up and the doors locked. The man was shot and killed. No bullet holes were found in the glass. How was he shot?* (Answer: The car was a convertible.)

The short of it *A midget in a circus is found dead on the ground with a sawed-off cane next to him. He died of a heart attack. What caused the attack? Clue: another midget is involved.* (Answer: The other midget wanted to be the shortest person in the circus. He sawed off part of the cane. The first midget thought he was growing and had a heart attack.)

Down and out *A man is found dead, lying face down in a desert with a sack on his back. How did he die?* (Answer: He jumped from a plane, but his parachute didn't open.)

Lily *A pond has one lily pad on it. The next day it has two. The next day four; next, eight. On the fifteenth day the pond was totally covered with lily pads. When was the pond half filled?* (Answer: On the fourteenth day.)

Night mystery *A night watchman is doing his nightly rounds in a warehouse. He goes down a hall and hears, "NO! Don't shoot, John! NO! NO!" BANG! The night watchman runs into the room from which he heard the shot. A doctor, a lawyer, and a plumber are standing above the dead body. The night watchman goes over to the plumber and says, "You're under arrest for murder." How did he know that the plumber was the murderer?* (Answer: The doctor and the lawyer were both women.)

Twins *Identical twins go into a bar and both order Scotch on the rocks. One of them drinks it slowly, the other quickly. Two hours later one of them dies. Which one and why?* (Answer: The one who drank it slowly. The ice cubes were poisoned. When they melted, they released their poison.)

Fred *My friend Fred was found on the floor, lying in a pool of blood and water and glass. How did Fred die?* (Answer: Fred was a goldfish.)

Create a Need to Know: Human Ecology

New York and Chicago boast some of the greatest American buildings. The notoriety of the Empire State Building and the Sears and Trump towers have contributed greatly to their population growth and tourism. Other cities, envious of the tourist income and recognition that these buildings bring, want a building of this stature of their own.

The contest. Our Town, USA, requests a proposal for a scale model of a building of the future. Design firms who want the contract must compete in a contest to build a scale model that meets criteria established by the Our Town planning commission. The criteria include descriptions of building height, quantity of construction materials, and construction time. These are summarized by the three graphs in Figure 3.1 that plot expected income in tourist dollars against building height, materials, and time. To win the contest, the design must pay attention to building height, materials, and construction time.

As shown by the first graph (Figure 3.1a), the height of the building and income expected from tourism are directly related. In the second graph

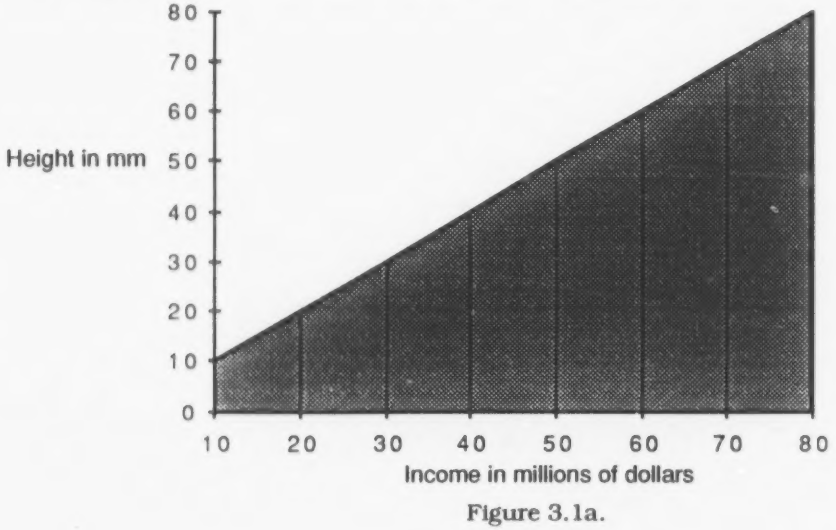

Figure 3.1a.

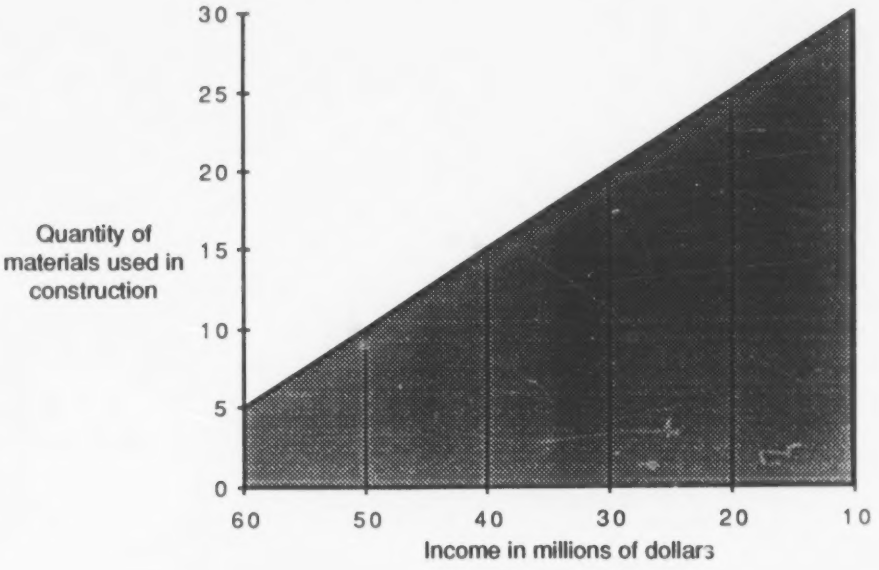

Figure 3.1b.

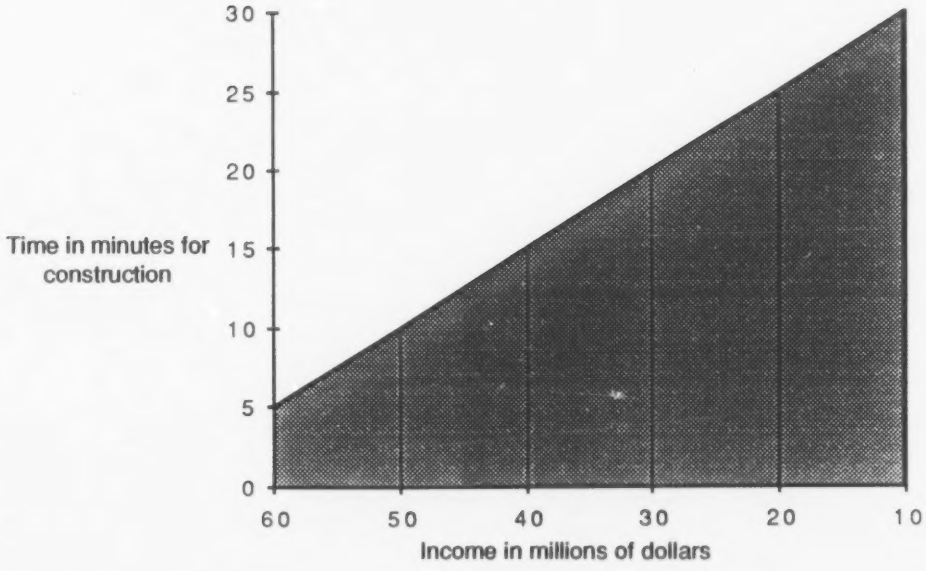

Figure 3.1c.

(Figure 3.1b), the quantity of materials used and income are inversely related; if materials are conserved, income will increase. The third graph shows that time spent in construction and income are also inversely related; if time spent on construction is conserved, income will increase.

The rules.

- Contestants working in teams will construct their models using whatever materials and tools are available and economical to use. For instance,toothpicks, playing cards, straws, and even human bodies are allowed. Used tennis balls are ideal material to nurture creativity and test the resourcefulness of youngsters. Saws to cut materials, hammers, and other tools should be at hand for students to use; they also give the contest a sense of reality.

The winner. The sky's the limit! Measure the heights of the scale models and convert height (through the use of the first graph) into dollars. Count the number of materials used (toothpicks, straws, tennis balls, or people) and convert into dollars. Do the same for time required to complete their creations (most groups finish within half an hour). Total the dollar amounts for each team. The team with the highest dollar amount is the winner.

Not only is this contest fun for students, but also it teaches some real-world lessons about what and where to build.

Processing the activity. The following questions and request for evaluation will help make this activity useful to students:

- ☞ Under real-world conditions, what factors other than the amount of materials and construction time would be considered in constructing a building of this size?
- ☞ Could this kind of building be sited anywhere? What kinds of question should be raised about its location?
- ☞ Evaluate your team's performance to plan and cooperatively build a skyscraper for Our Town, USA.

Challenge to Know: What and Where to Build

Most youngsters dream about the home they hope to build and where they would like to live. The opportunity to put their dreams on paper and build a scale model for the future is a challenge that grabs their attention. This project makes students aware of the impact humans can have on the indoor as well as the outdoor ecological conditions. Begin by brainstorming questions to raise about a home designed for living in the future. Here are some questions that other students have raised:

- ☞ What should be the source of energy?
- ☞ What should be the design of the house?
- ☞ How many rooms should it have?
- ☞ What will be done with the wastes?
- ☞ What kinds of materials should be used to construct the house?
- ☞ Will drinking water be a problem?
- ☞ How should the rooms be designed?
- ☞ Where should the house be built?
- ☞ What direction should it face?

Show How to Know

Where to get ideas. Trends (patterns) in energy use, water conservation, waste management, and agriculture can seed ideas for designing the house of the future. Start with what students already know, then suggest that they research the current trends. Newspapers and periodicals are convenient resources for researching the status of renewable energy resources, solar technology, and new ways to grow crops. The following trends were current during the late 1980s and early 1990s:

- United States oil reserves are decreasing and will last only a few years at current production levels. Almost two-thirds of the world's oil is in the Middle East.
- During the 1980s energy-efficient improvements (such as insulation) were the most important energy resource in the U.S., exceeding the contributions from coal, nuclear energy, oil, and natural gas.
- The sources of water fit to drink are shrinking due to groundwater contamination, waste, and population growth.
- Water and soil can absorb some human waste as fertilizer, but the cleansing capacity of local environments is being exceeded by many communities.
- Radiation specialists are becoming concerned that the most damaging exposure to radioactivity occurs in the home. The radiation source is radon, which seeps from soils through basement walls.
- Organically grown food is no longer a fad. The rise in demand for it insures that plants will be be grown free of the chemicals that are now used as fertilizers and pesticides.

- With changes in climate forecast for the future, the supply of agricultural products, as well as their costs, will be unpredictable.
- Traces of formaldehyde, benzene, carbon monoxide, and nitrous oxide have been analyzed in household air. A new kind of pollution called indoor pollution has presented new kinds of health hazards.

These trends suggest a starting place for designing a house for the future. Welcome students' ideas that benefit the indoor environment through improvements in heating and cooling, waste management, drinking water, etc. Help students visualize these ideas by showing them how to design a floor plan for a future home.

A floor plan for ideas. A floor plan requires students to put their ideas on paper and test the practicality of their creations. Encourage them to consider the aforementioned trends in energy and water use, waste management, pollution, food resources, etc. A scale recommended for the floor plan is 1/8 inch = 1 foot. A student's floor plan is shown as an example.

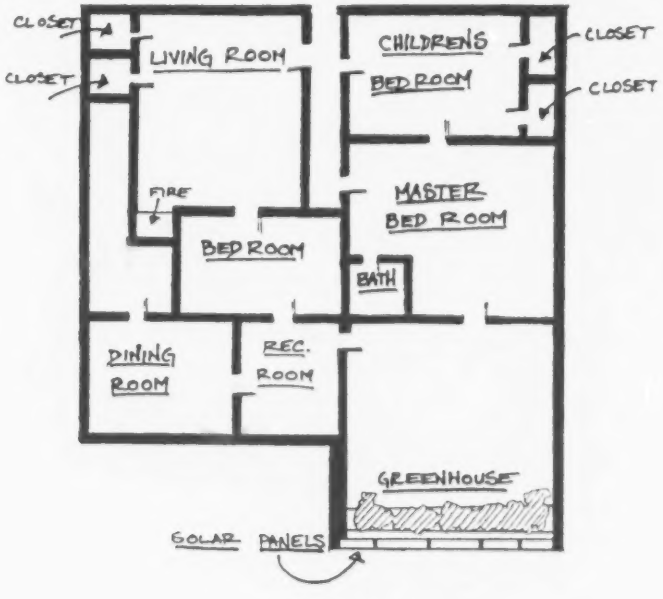

Figure 3.2.

A three-dimensional model. The following steps show how to create a three-dimensional figure from the floor plan using what is called an isometric drawing. This three-dimensional figure can then be used by students to construct a model to scale.

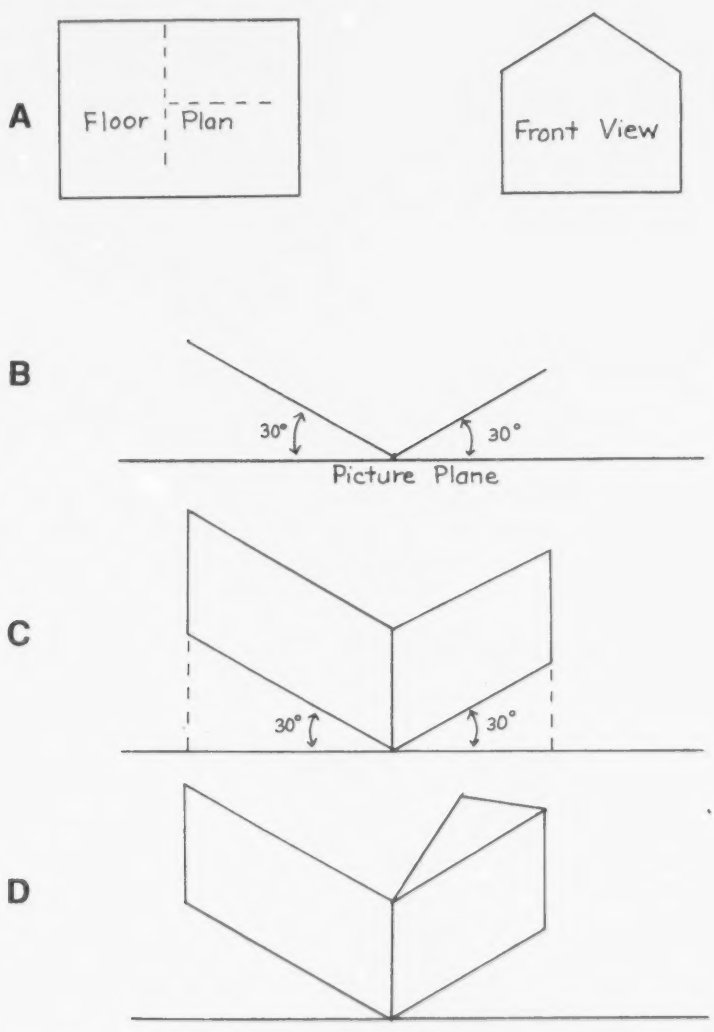

Figure 3.3. *Floor plan and elevation, picture plane, walls, and roof.*

1. Alongside the floor plan, draw the elevation (projection of the front view) of the house to scale. Use a scale of 1/8 inch = 1 foot.

2. Draw a picture plane horizontally across the page. At a point midway along the picture plane, draw a corner of the house at a 30-degree angle from the plane. Draw the two sides to scale.

3. Raise the walls, drawing them perpendicular to the picture plane. Draw their height to scale.

4. Complete the drawing by adding a roof. Use the midpoints of the sides of the house to center the peaks of the roof.

Build a scale model. The rendering of the floor plan to a three-dimensional figure can be used to build a scale model of the home. From the dimensions given by the model, cut out the walls and roof from cardboard or foamboard and glue them together. A youngster's scale-model home is shown as an example in the photo below.

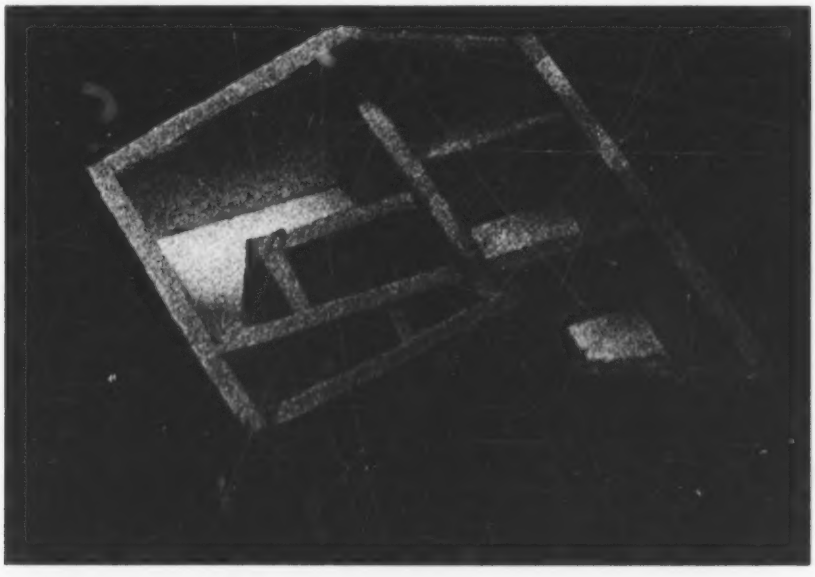

Figure 3.4.

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Apply Know-How

Holding a design contest helps students recognize the value of a healthy indoor ecology as well as an outdoor ecology. Give awards to the designs that best answer questions raised earlier about real-world trends in energy production, water use, waste management, and food production. The student team that earns the greatest amount of points based on the criteria below will be judged the winner. House designs will be judged on their ability to solve all or some of the following problems.

Problems to solve	Points earned
Heating and cooling a house using alternatives to coal, gas, and oil	200
Heating water using alternatives to coal, gas, and oil	50
Conserving water used for drinking and waste removal	100
Recycling solid wastes	300
Growing foods at home year round	200
Conserving time spent maintaining a house	100
Preventing radon leakage through house walls	300
Preventing indoor pollution from harmful chemicals	100
Conserving living space (for example, by building upward instead of outward)	300
Total possible points	**1,650**

Know How to Inspire Cooperation

Ideas created on paper about what to build must be tested for their compatibility with the environment. This raises questions about where to build. New information from studies done in the last two decades has taught us about the connection between humans, plants, and animals. Development of land to increase living space affects wildlife, soil, air and water. The effects may be felt next door or thousands of miles away. The slashing and burning of the Amazon forests a continent away, for instance, impacts the climate of the United States. The destruction of a marsh can affect the drinking water of a neighbor a mile away.

Until recently, it was possible to build almost anywhere. Recognizing the need to protect the environment, cities, states, and the federal government have begun to pass environmental protection laws. It is no longer possible to build just anywhere. It is now the builder's responsibility to evaluate the suitability of real estate for developing. Part of that responsibility includes making an environmental impact statement.

Study the impact on the environment. An environmental impact statement evaluates the environment for development by studying areas such as:

Wildlife habitats	Topography
Vegetation	Historic and scenic value
Wetlands	Aesthetic value
Geology and soils	Socio-economic condition
Drainage	Access and traffic
Hydrology and water quality	Noise

Acting as consultants, a team of biologists, hydrologists, geologists, civil and traffic engineers, land-use planners, and historians often cooperate to research a piece of real estate for potential development. Through raising the right kinds of questions, they will predict the effect of development on the potential for soil erosion, loss of flora and fauna, destruction of wetlands, change in traffic patterns, etc.

Ask students to work as a team to weigh the pros and cons of building on a piece of real estate chosen for development. Using the following guidelines, coach students on how to make an environmental impact statement.

Select a site for building. Select two sites to consider for building the future house. The sites should be of equal size and large enough to accommodate the dimensions planned for the house (see scale model). The real-estate parcel whose ecological value is judged to be the greatest should be conserved; the other parcel should be developed for building.

Map the two sites. From a regular map that shows both sites, outline their locations. This will show the relationship between the sites and neighboring wetlands, roads, and other environmental features. Ideally, the two sites should be mapped to show location of geological features, terrain, vegetation, and wetlands. Shown on the opposite page is a map with a key to its biological and geological features drawn by students of a site they evaluated for development.

Sample along a transect. Because of the time required to sample the entire area, take only representative samples of land. It is normal procedure to sample along a line known as a "transect." It should be the distance of either the width or the length of the real estate and sited through the most diverse habitats of each. By walking along this line, an inventory of plants and animals in the area may be taken.

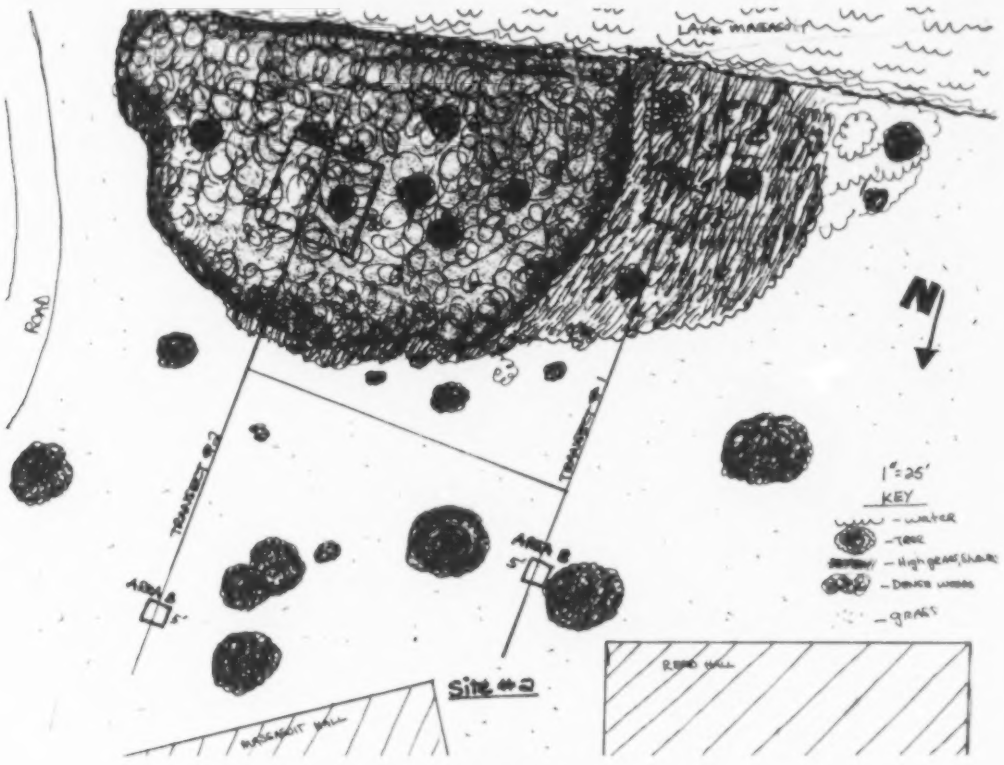

Figure 3.5.

Survey the vegetation. The ecological value of an environment is influenced by the number of plant species living together. As the diversity (the total number of different species) of plants increases, the more valuable the land becomes. The reasons for this are many. The number of plant species decides the number of animals that can inhabit an environment. Not only do plants provide food for animals, but they provide shelter and living space as well. Together, they provide "niches" in which animals live. Stability is also a factor of diversity. The more diverse the habitat, the more stable it becomes.

Sample the kinds of vegetation growing on both pieces of land along transects of equal size. Make an inventory of the number of different plants (it is valuable but not necessary to know the names). Students may want to collect and preserve representatives of each plant, but be sure not to

pick any endangered species. Count the species. The total number of different kinds of plants equals the ecological value of each parcel of land. This number is the point score for the parcel.

Survey the animals. Like the variety of plants, the number of different kinds of animals influences the value of the land. Along the same transects, record the different kinds of animals. It is often necessary because of the secret habits of animals to look for signs instead of the animals themselves. Clues from tracks, scats, fur, and browse from feeding are among the signs of an animal's presence. Homes engineered by animals are other clues. Here are suggestions for locating these signs:

- ☞ Look up. If a nest is made of leaves (for summer living) and branches (for winter living), it's the home of a red or gray squirrel. If it is constructed of grass, leaves, twine, even plastic, it is likely a bird's nest.
- ☞ Look down. Openings to subterranean chambers are signs of ground squirrels or chipmunks. Tunnels elevated slightly above the ground are signs of moles or shrews.
- ☞ Look ahead. Holes in tree trunks are entrances or exits to homes for field mice or voles.
- ☞ Look under. Fallen logs may conceal the homes of insects, amphibians, and reptiles.
- ☞ Beware. Apartments or condominiums containing hundreds of insects may be homes to bees or wasps.
- ☞ Count the number of different animals from either their homes or other signs. Again, the total number equals the ecological value. This is the point score for the parcel.

Survey the wetlands. Lands that are covered by water for most of the year are called wetlands. Wetlands known as marshes, swamps, and bogs are characterized by particular kinds of plants, animals, and soils. Once considered unattractive, insect-ridden, and dangerous, wetlands are now valued to the point of being protected by law.

Research has shown that wetlands are major contributors to the hydrological cycle—the pattern of evaporation, precipitation, and flow of water to the sea. They reduce erosion and the destructive potential of severe floods. Wetlands can absorb nutrients and improve water quality by holding nutrients back when they are in abundance and releasing them when they are needed.

Wetlands also produce oxygen and nitrogen for the atmosphere. And wetlands are living museums where wildlife can be observed in person. As the area of wetlands increases, the value to the environment increases. Estimate the area of your parcel covered by wetlands and use the graph to estimate the land's ecological value.

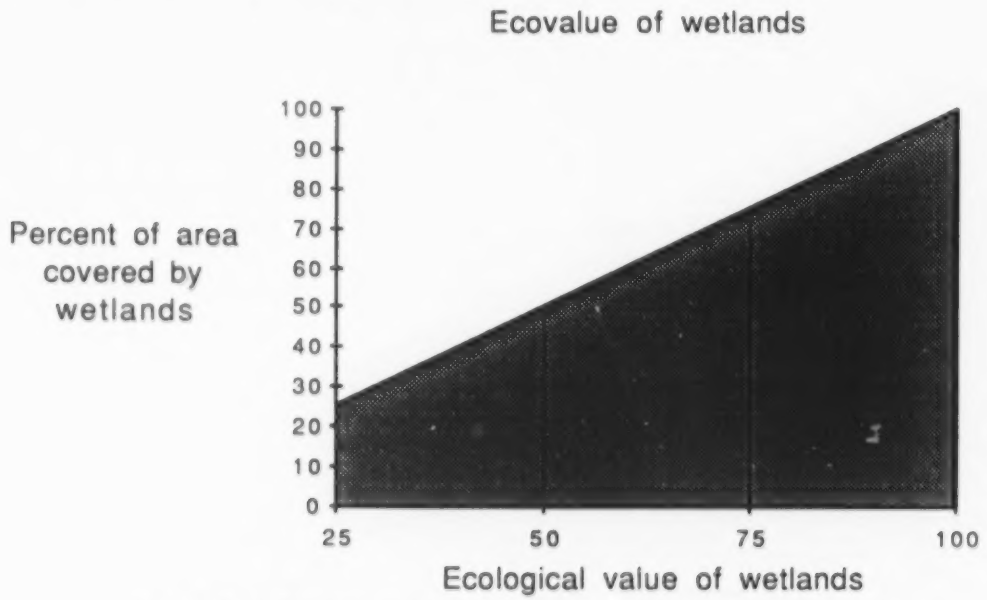

Figure 3.6. *Estimate the ecovalue of the site based on the percent of area covered by wetlands.*

Survey the vegetative layers. The layers of vegetation growing in an ecological community can number as many as four: (1) the canopy, (2) the subcanopy, (3) shrub, and (4) ground-cover layers. The vertical stratification of plants is important to creating habitats for wildlife; the more layers that are present, the more types of wildlife that can be supported.

The uppermost layer is called the canopy. Characteristic of woods and forests, the canopy is the covering of mature trees (maple, oak, etc.) that shade the forest floor. Beneath the canopy is a subcanopy of smaller, immature trees or saplings, whose trunks are no more than four inches in diameter, that grow in the shadow of the taller trees. The shrubs are multistemmed, woody plants that grow under the subcanopy. These include plants such as blueberry, rhododendron, and mountain laurel. Finally, the ground cover of grasses, wildflowers, ferns, and similar plants form the remaining layer.

The ecological value of the vegetative layers is partly their ability to provide homes and food for animals. Count the number of layers present and determine the point score with the aid of the chart.

Number of Layers (Diversity)	**EcoValue Point Score**
1	25
2	50
3	75
4	100

Survey the number of ecotones. Ecotones are "edges" in ecological communities, such as where a forest grades to a grassland or a pond meets the shore. This zone of transition between two neighboring communities is rich in the number and kinds of species characteristic of both communities. Species such as deer, bobwhite, catbirds, and squirrels that live in the ecotone between a forest and grasslands benefit from both environments. They feed upon the grasslands and use the forest to escape from predators. The ecotone also provides a safe passage between each environment.

Count the number of ecotones on each piece of real estate and determine from the chart a point score for their ecological value.

Number of Ecotones (Diversity)	**EcoValue Point Score**
1	5
2	10
3	15
4	20

Survey the endangered species. Species such as the peregrine falcon, the timber rattlesnake, the Puritan tiger beetle, Bush's sedge, and mountain cranberry are carefully watched. Because they are on the verge of extinction, they have been classified as endangered. Species that are identified as endangered are protected under the law.

Land developed for building often upsets fragile ecological systems. As these systems vanish, they take with them animals and plants that have evolved within their boundaries over thousands of years. The destruction of species by human activity causes the loss of diversity that is essential to any society or community.

Because they are rare, endangered species are best identified by experts. It is usual, however, for representatives of state governments (such as fish and wildlife agencies) to know the location of their state's endangered species. Call or write your state government to determine where endangered species have been located. If an endangered species is located on the property selected for development, construction would be prohibited. If the species neighbors your site, determine a point score for ecological value from the chart.

Number of Endangered Species	EcoValue Point Score
1	250
2	500
3	750
4	1000

Tally the scores. Total the scores recorded for all categories on each site. The site with the highest score has the highest ecological value. This is the parcel to conserve; the other site could be developed.

Scores	Site 1	Site 2
Wetland	_____	_____
Vegetative diversity	_____	_____
Animal diversity	_____	_____
Ecotone number	_____	_____
Vegetative layers	_____	_____
Endangered species	_____	_____
Total scores	_____	_____

Remind students that knowing the right question to ask is often the key to finding the solution. No one is born with this talent. It is learned the hard way through trial and error, just as you might learn to play a guitar or ride a bike.

4 Learn How to Make Predictions with Confidence

The willingness to take risks is part of being a scientist. When Stanley Pons and Martin Fleischman wondered if energy produced through nuclear fusion could be obtained at room temperature, they took great risks: the risk of getting it wrong, the risk of losing investments in both money and time, the risk of ridicule, and so on. Making predictions is a high form of risk. Scientists such as Keppler, Galileo, and Newton took risks staking their reputations, careers, and sometimes their lives. But scientists are not the only people who take such risks.

Actuaries (whose forecasts decide success or failure of the insurance industry), athletic scouts (whose recruits are future successes or failures), police detectives (whose hunches lead to the arrest of crime suspects), and stockbrokers (whose forecasts guide investments) all provide examples of the kind of risk taking that scientists must also be willing to take. Experiments that encourage students to take the risk of making predictions and applying them to real-world problems are the substance of this chapter.

We begin with an exercise called "What If" to help students make predictions and take risks with creative ideas. Predictions are not just wild guesses: They are based on understanding of patterns. Once students understand the rules, they learn to make predictions with confidence. This is the emphasis in "Human Evolution—What's Next?"

Skills	Activities	Materials
Developing risk taking through making predictions Applying prediction skills to problem solving	What If? Human Evolution—What's Next?	Human skeleton (disarticulated) Clay Graph paper Tape measures

What's Next invites students to predict the future of the human skull. Using skulls from the human family album, students trace evolutionary changes in jaw size, cranial capacity, and other skull parts. Students learn how to extrapolate patterns from the past to make predictions for the future. Information from predictions about separate skull parts is used collectively by student groups to design a future human skull form clay.

Using the model to make predictions, students apply know-how to forecast what's ahead in human nutrition, health, longevity, and technology. Autopsies of Egyptian mummies help supply research information needs to reconstruct the history of such changes.

This project challenges individual creativity, develops confidence in higher thinking skills, and interests young minds. Moreover, the scientific method, with emphasis on predictions, is employed throughout as a model for solving problems,

What If?

Goal. This activity shows how to make educated guesses and provides an opportunity for students to take risks with their creative ideas.

Introduction. Who is now daydreaming? What are your dreams? All of us enjoy daydreaming new ideas, but not aloud or in public. How often do you see your ideas credited to others who had the courage to share them publicly? Risk-takers dream aloud and ask, What if?

Stanley Pons and Martin Fleischman wondered if nuclear fusion could occur at room temperature. Inventor Thomas Edison's dreams of making people happy with his inventions led to a record number of patents. Charles Townes asked in 1951, What if shorter wavelengths of light could be harnessed? This dream led to the powerful laser. More than a century ago, inventors were ridiculed for wondering if we could ever see images using electricity. Today, half a billion people have television sets.

Among those whose job it is to ask "what if" are architects, inventors, land developers, economists, and city planners. Encourage students to daydream and share their dreams with others. Their creativity is the raw material for the next generation of science.

The rules.

- The leader reads, What if . . .? and participants respond, then . . . Encourage students to brainstorm individually and then share their ideas with others. Reverse roles. Ask students to come up with their own What if statements for their peers to finish.

What If?

- ☞ What if the polar ice caps melted? Then . . .
- ☞ What if the oceans froze during winter? Then . . .
- ☞ What if Matter met Antimatter? Then . . .
- ☞ What if the sun were blocked for three months? Then . . .
- ☞ What if people could be frozen, then rethawed? Then . . .
- ☞ What if humans lived to their predicted age of 128 years? Then . . .
- ☞ What if trees dropped their leaves twice instead of once per year? Then . . .
- ☞ What if the pull of gravity were halved? Then . . .
- ☞ What if enzymes disappeared from animals and plants? Then . . .
- ☞ What if the sun came up in the west instead of the east? Then . . .
- ☞ What if it were possible to tap icebergs for fresh water? Then . . .
- ☞ What if a new smart pill was created? Then . . .
- ☞ What if knowledge could be transferred by injection? Then . . .
- ☞ What if a cure to all diseases were found? Then . . .
- ☞ What if the tropical forests were all cleared of trees? Then . . .
- ☞ What if brain transplants were possible? Then . . .

Real-world examples. Predictions about the following have significance to a number of different sciences and occupations. By knowing the rules, predictions can be made with a high degree of confidence. Look for a pattern (trend) in each example, then extend the pattern to predict the future.

Chemistry: The most stable atoms known are those of the inert gases helium, neon, argon, krypton, xenon, and radon. These gases share the same column of the periodic chart. What will be the next inert gas? Predict its chemical properties, atomic number, atomic weight, and electronic configuration (look for a pattern in the elements that share the same column, then make a prediction based upon the pattern). Give the new gas a name.

Math: Mathematics looks for patterns in a world that appears random. At AT&T Bell Laboratories, over five thousand sequences of numbers that contain a pattern are stored. Here is one such pattern: 1, 3, 6, 10, 15. What's next? (Answer: 21, 28, 36. Each number is the sum of its number position in the sequence and the previous number: 21=6+15.) This pattern is often used on IQ tests.

Here is another pattern: 3, 5, 8, 13, 21. What numbers come next? (Answer: 34, 55, 89, 144. Each number is the sum of the two before it: 34=13+21.) This sequence of numbers is called the Fibonacci Sequence. Examples of it can be found in nature, such as in the way pinecones and pineapples form.

Ecology: An increased amount of carbon in the atmosphere underlies the greenhouse effect, which is predicted to have a dramatic effect on the world's climate. Beginning in 1965, the following amounts of CO_2 have been recorded.

1965: 319 parts per million

1975: 329 ppm

1985: 341 ppm

1995: What's next?

Earth science: Californians, particularly those who live near the San Andreas Fault, live with a constant threat of earthquakes. When will the next one occur? Major earthquakes have been recorded in 1857, 1881, 1906, 1922, 1934, 1966, and 1989.

Biology: An analysis of fossils shows that species have periodically died in staggering numbers in what has been called mass extinctions. When will the next extinction occur? The history of fossil evidence records extinctions at 11, 38, 65, 91, 125, 144, 163, and 194 million years ago.

Astronomy: Increased solar activity recorded by increases in sun spots and the northern lights can have serious effects. Major power blackouts and interferences with communications can result. The ability to predict the sun's activity would permit people to plan for these kinds of emergencies. Past peaks in solar activity were recorded (approximately) in 1990, 1979, 1968, 1957, and 1946. When is the next peak expected?

Careers: Making accurate predictions based on patterns is the primary task in many careers. The following types of professionals could be invited to class or, ideally, visited at their places of work to learn the role predictions play in their jobs.

- Meteorologist
- Actuary for insurance company
- Professional sports scout
- Police detective
- Stockbroker
- Economist
- Seismologist
- Military strategist
- City planner
- Health administrator
- Civil defense coordinator
- Las Vegas odds maker

Create a Need to Know: Human Evolution

Dead men do tell tales. From human skeletal remains, accurate deductions about a late person's life can be made. This is the evidence from which much of the story of our own evolution has been written. Each of the 206 bones and 32 teeth in the human body has a story to tell. This is because each of life's significant events—injury, illness, childbearing—leaves its marks as bones grow. It is possible to reconstruct the life-style, age, sex, health, and more, just from the skeleton. Lead students in brainstorming about how the following traits can be deduced from bones. What bones record information about nutrition, height, and so on? (The emphasis throughout the following exercises is on trends rather than terminology. Students need not be already familiar with specific anatomical terms.)

What bones reveal. Bones can tell about a person's nutrition, height, sex, physique, cranial capacity, health, age, and race. They will even give clues about how much a person exercised and whether or not they gave birth to any children. The following sections describe some of the clues a skeleton might give. This figure of the human skeleton can be used as a reference to locating bones of an actual skeleton.

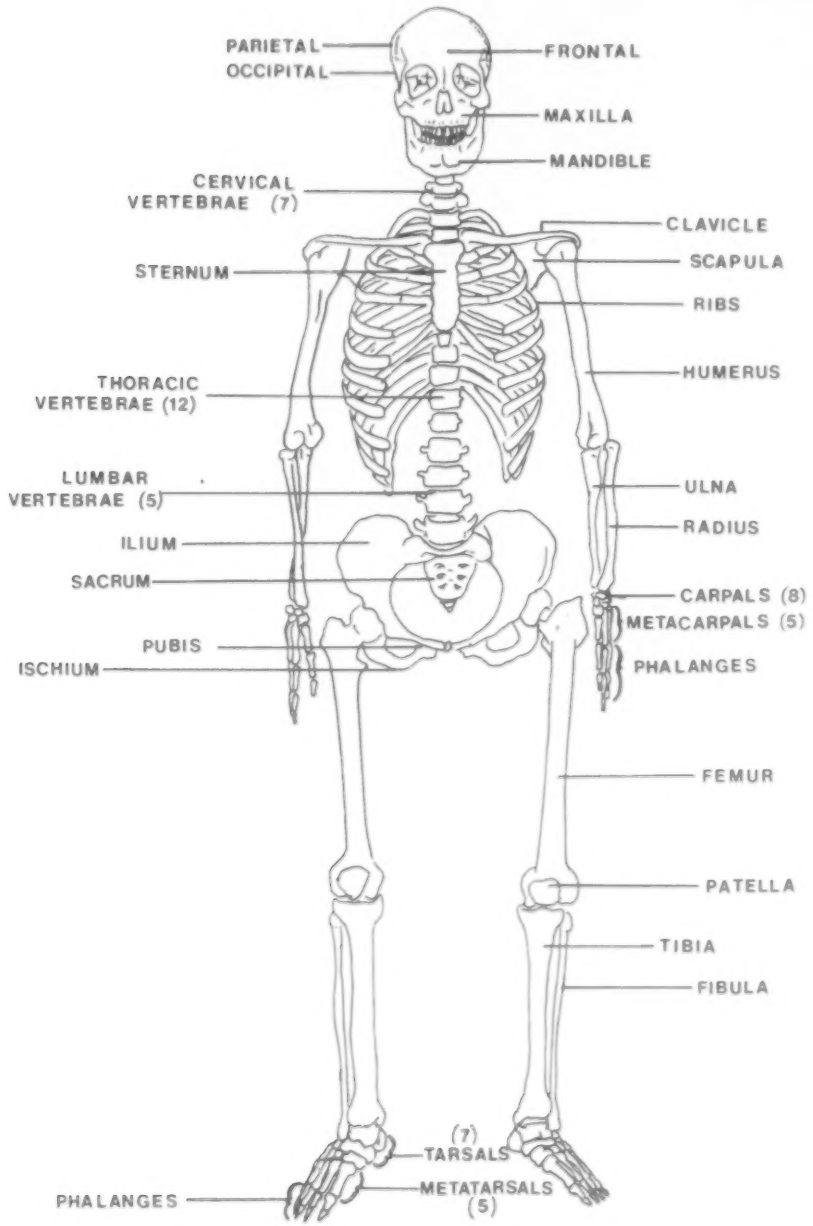

Figure 4.1. This figure of a labeled skeleton can be used as a reference to locating bones on an actual skeleton.

Height: From the length of the femur, located in the thigh, a person's adult height can be estimated. The femur is the most massive bone and is often found with the remains of a skeleton. The femur serves as a pole to which the large muscles attach. Its role is to move the body through space.

As the femur grows, cartilage is converted to bone. This process is called ossification. Growth of bone occurs from about eight weeks of life to puberty, when ossification ceases. Because bone growth occurs in predictable spurts, age as well as height can be estimated from the femur.

To get someone's height, measure the length of the femur (thighbone) and do the following arithmetic.

LENGTH

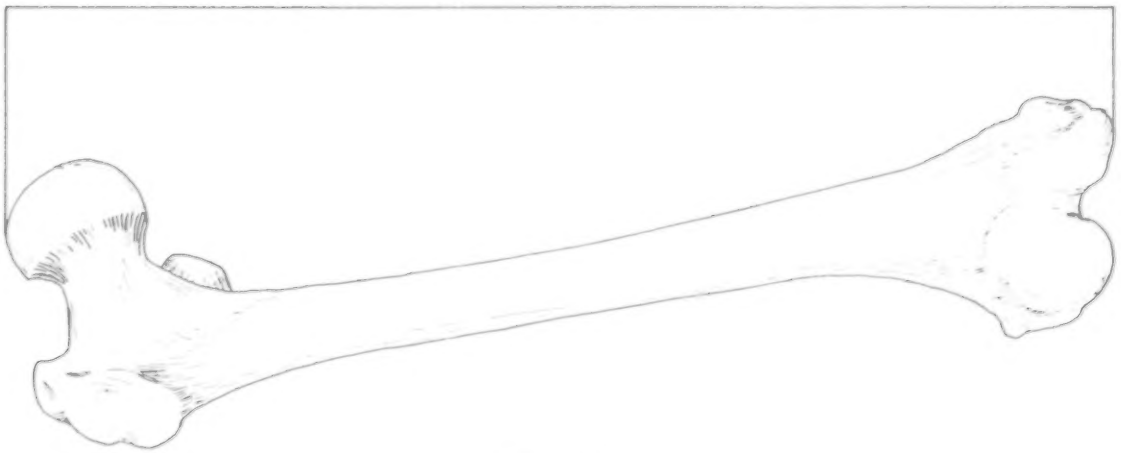

Figure 4.2.

2.6 x _____(femur in cm.) plus 65= _____(height in cm).

Convert cm to inches= _____cm x 0.4 = _____(inches).

Age: The skull, pelvic girdle, femur, and teeth are clues to age. Up to the age of eighteen years, the length of the femur can be used to estimate age. After the age of eighteen, tooth wear and changes in the pelvis and skull can be used to estimate age. The sutures of the skull, for example, are clearly distinguished in young skulls. When the skull ages, the spaces between bones narrows, making the sutures less distinguishable.

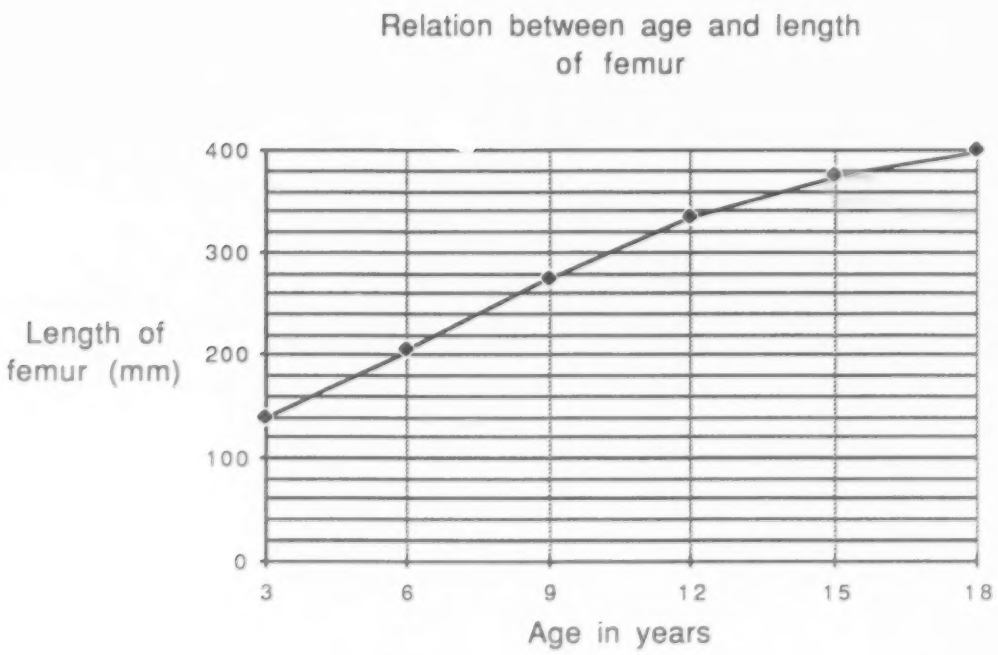

Figure 4.3. *The relation between age and length of femur.*

Sex: Clues to a person's sex are found in the pelvis. Parts of the pelvis called the ischium-pubis index, angle of the pubic arch, width of the sciatic notch, and width of the subpubic angle can all be used to determine sex.

The pelvic girdle is the bone complex located between the vertebral column and the bones of the upper leg. The girdle serves to provide support for the viscera and for the trunk by transferring weight equally to the legs. It has undergone considerable modification in the past 4.5 million years, and its change is important to understanding the evolution of walking on two instead of four legs. The hipbone consists of three portions that fuse by the twelfth year; they are the ilium, pubis, and ischium. The ilium is the largest. Its upper margin is the iliac crest. An indentation along its posterior margin, called the sciatic notch, is an anatomical landmark that can be used to determine sex in skeletons. The pelvic bone we sit on is the ischium. The third, the pubis, consists of two bones, called the superior and inferior rami. The angle formed where the rami of the left and right pubis meet is called the pubic arch. This arch, along with the other skeletal differences that exist between males and females, can be used to deduce the sex of skeletons.

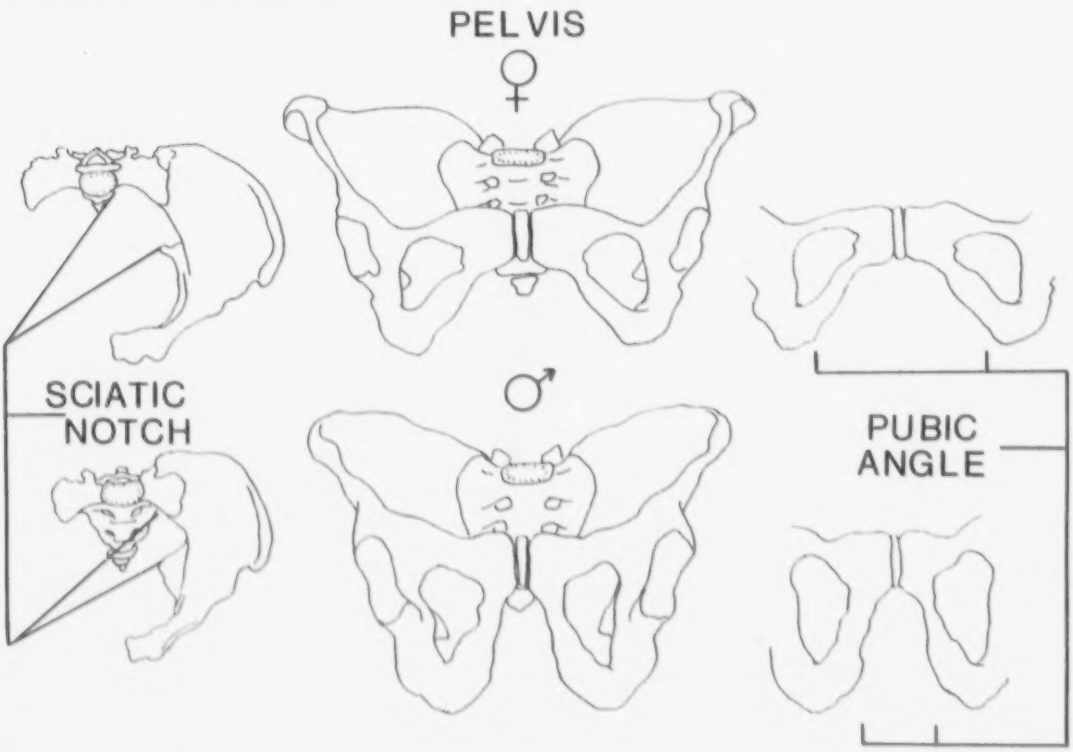

Figure 4.4.

Physical condition: The robustness of bones such as the femur and humerus and their anatomical landmarks (processes) are clues to the frequency of exercise. Bone processes, for example, become larger when the muscles to which they are attached become stronger.

The humerus, like most long bones, consists of a shaft or body with two expanded ends. This bone, which serves as the lever of the upper arm, receives muscles at various points along the shaft, called insertions, and is the origin of yet other muscles. The points of insertion or origin are anatomical landmarks.

The median and lateral condyles of the humerus, for example, are the origin of muscles that move the forearm. Look at these processes on the humerus, where these muscles attach. Are they pronounced? You can tell how active a person was, or how much exercise and how muscle-bound the arm was by noting the size of these processes. One can distinguish, for example, the skeleton of a stonecutter from a nobleman simply by comparing these landmarks.

A particular enlargement of the ulna (one of the two forearm bones) is the result of habitual throwing. This enlargement is common to spear-throwing hunters as well as their counterparts today, baseball pitchers. Irregular grooves near the knee are marks of people who spent much of their time squatting instead of sitting. These marks are seen in skeletons of Neanderthals and are perhaps due to squatting by fires. A pronounced curvature of the spine toward one side probably resulted from a lifetime of carrying heavy loads.

Health: The markings and density of bones often reflect pathological conditions. Feel the weight of the femur. Very light bones signal loss of calcium, perhaps caused by disease such as osteoporosis. If the femur is bowed, the person may have suffered from rickets, a bone problem caused by not enough vitamin D.

Look for signs of trauma, such as fractures. Traumatic fractures occur when abnormal forces are applied to bone. Fractures near the wrist are often due to falls; fractures at the middle of the arm are often due to blows. Incomplete fractures occur in bone that has not fully calcified, typical of children. Hairline fractures are small fractures that do not displace the bone.

Clues to some diseases can be found in the orbits of the skull. Bone porosity and pitting of the upper margins of the orbits of the eye, for instance, indicates blood anemia. A smaller than normal spinal cord opening (foramen magnum) in the skull is a mark of stunted growth, often caused by childhood disease or poor nutrition. Disruptions in growth are recorded by the teeth. Rings around the circumference of teeth, like growth rings of a tree, record periods of stress, disease, or poor nutrition.

Race: Race can be guessed from measurements of the sacrum, which is a triangular-shaped bone formed by the fusion of five bones of the lower spine. Joined to the pelvis by ligaments, it helps support the lower back. Measure the breadth and the length of the sacrum (Figure 4.5). Calculate the sacral index from the formula s. i.= breadth/length. Compare the index with standards in the table to guess the race of the skeleton.

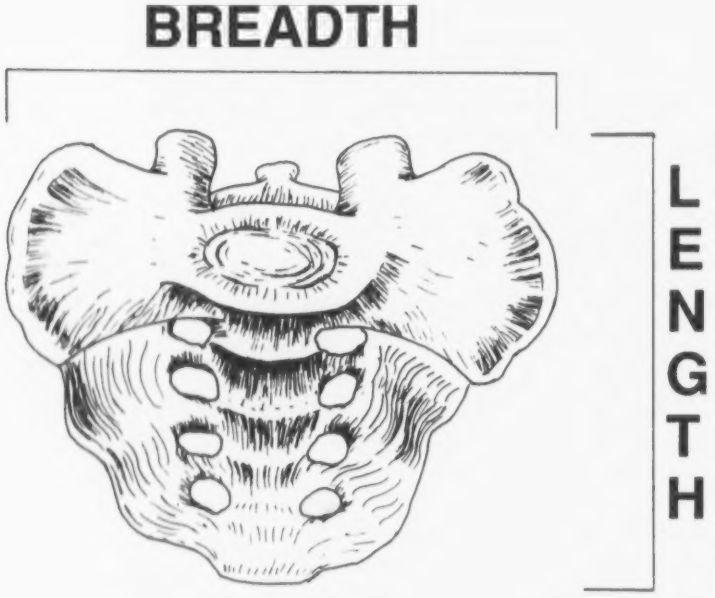

Figure 4.5.

Race/Nationality	Male	Female
Egyptian	94.3	99.1
Black	91.4	103.6
Caucasian	102.9	112.4
Japanese	101.5	107.1

Figure 4.6. *Examples of sacral indexes.*

Nutrition: Much about a person's nutritional history can be accurately guessed from the skull and skeleton. Large jaws reflect a diet that included hard objects such as bone, raw meat, and plant stems. Measure the height of the jaw of the actual skull or take a measurement from a photo. Place the tips of a caliper between the chin and the base of the nose (nostrils).

Record measurements in millimeters. Compare this to the total height of the head. Measure the height of the head between the chin and the crown of the head. Record the measurement in millimeters. Divide jaw height by head height. Multiply by 100 to determine what percent of the head height is jaw height. Record the percentage value.

Jaw Height	Head Height	Percent Jaw of Head

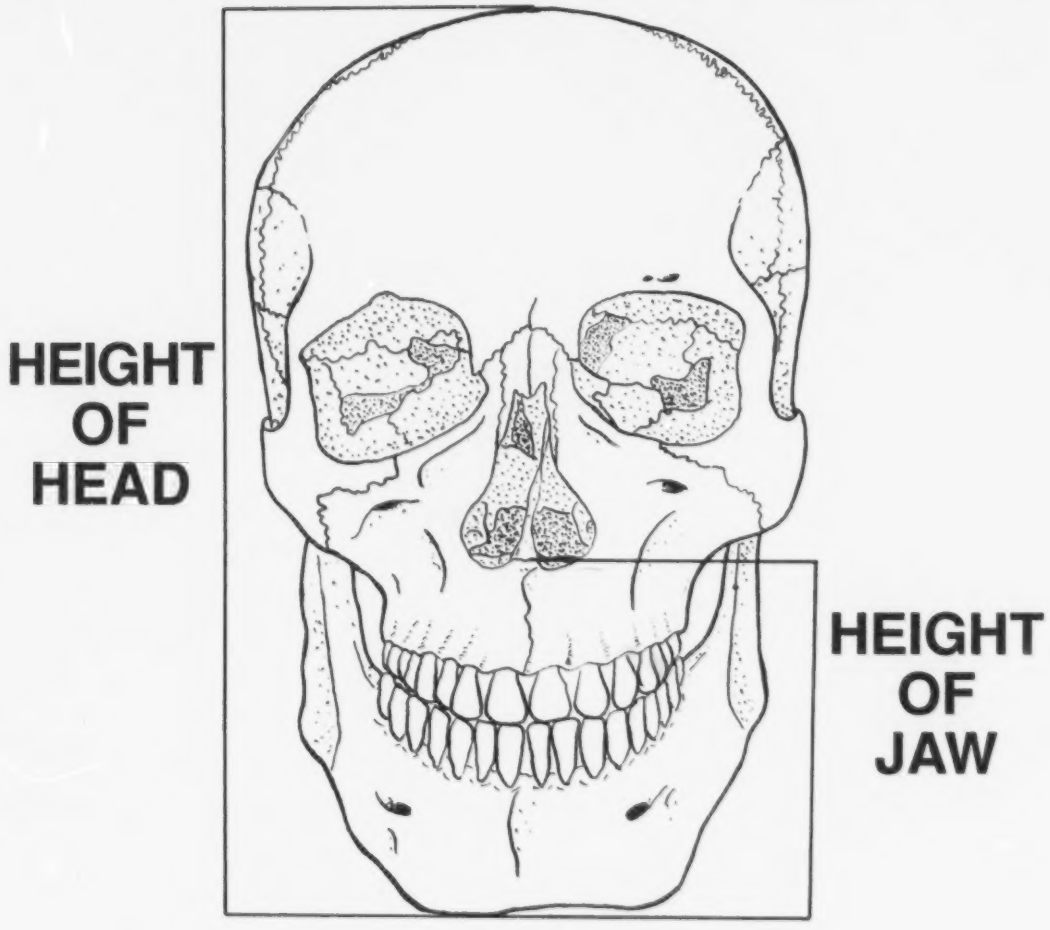

Figure 4.7.

Dominant molars are clues to plant diets, and prominent canines are clues to diets consisting largely of meat. The dental formula is often a reflection of the jaw size. Count the number of molars, premolars, canines, and incisors.

Stress caused by poor nutrition is indicated by dental crowding. Another clue to poor nutrition is called jaw asymmetry. This refers to the fact that one side of the jaw, including one or more teeth, is larger. Tooth enamel that partially covers the teeth or is thinner than normal (enamel hypoplasia) is associated with nutritional deficiencies as well. Look for cavities. Estimate their number. Caries are indicators of carbohydrates in the diet. Their frequency increased when meat was replaced with carbohydrates during the Agricultural Revolution.

Handedness: Examine the top of the skull. Draw a midline through the skull, dividing it into two halves. Is one side larger? This is the dominant side of the brain. Because it controls the opposite side of the body, you can deduce which hand was favored.

Cranial capacity: The volume of the cranium is a rough measure of brain size. The capacity of human skulls varies between 850 and 1,700 cubic centimeters. Among members of the same species, there is no relation between cranial capacity and mental capacity. Differences in cranial capacity between species may reflect differences in speech, tool-making abilities, or intelligence.

Methods for measuring capacity are inexact. One way is to fill the cranium with sand and then measure the volume of water displaced by the sand. Another method uses a formula that is a product of skull breadth X length X width. Figures 4.8a and 4.8b show how to measure the length, breadth, and width of the skull.

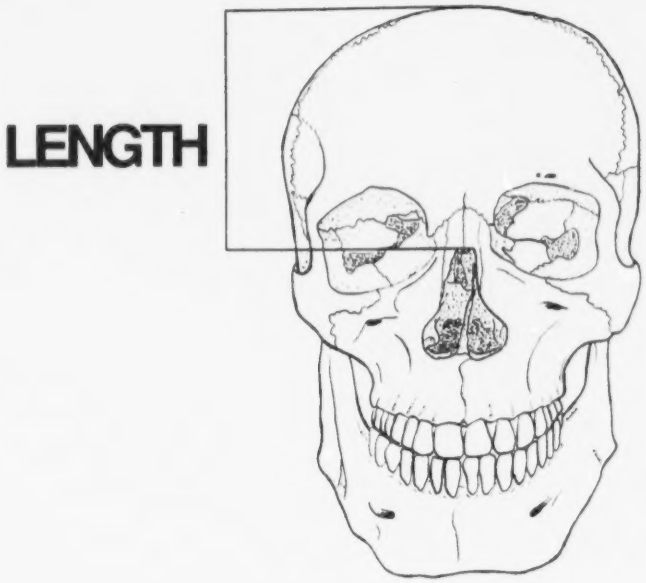

Figure 4.8a. *Front view of skull shows how to measure the length of the skull.*

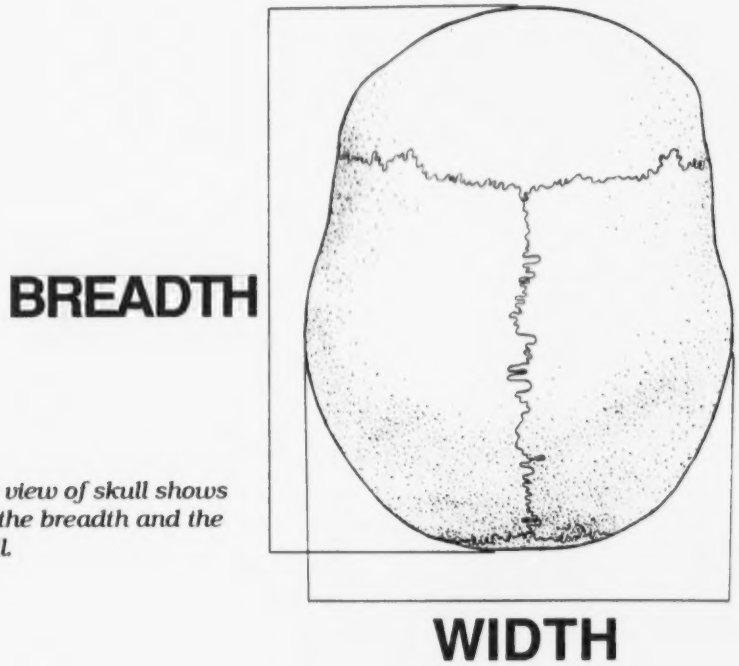

Figure 4.8b. *Top view of skull shows how to measure the breadth and the width of the skull.*

A human osteobiography. Skeletons are life histories recorded in bone. The remains that you have examined contain clues to various facets of the owner of this skeleton. Working as a group on one of these facets, share your findings with others.

- ☞ What was the sex of the person?
- ☞ What was the height of the person?
- ☞ What can be said about the person's health?
- ☞ What is the cranial capacity?
- ☞ What can be said about the nutrition of the person?
- ☞ What was the race of the person?
- ☞ What was the age of the person at death?
- ☞ What was the physical condition of the person?

Challenge to Know: What's Next?

Bones left behind by our ancestors give us a window to the distant past. They are clues to the evolution, perhaps, of modern-day humans. From clues such as these, we recognize several trends distinctive to the evolution of humans. These include increases in stature and dexterity, flaring of the pelvis, reduction of the forelimb in relation to the hindlimb, loss of an opposable toe, and a reduction in the lumbar region of the back. The skull has undergone dramatic changes as well, which are easily recognized by the beginning student.

Place four human skulls or their photos (Figure 4.9) randomly in front of students. Challenge students to arrange them from the most primitive to the most advanced. Then, ask them why they arranged the skulls in the manner they did. This gives students practice in recognizing general trends.

Figure 4.9a. *Photo of a skull of* Australopithecus *(courtesy of Carolina Biological Supply, Burlington, N.C.).*

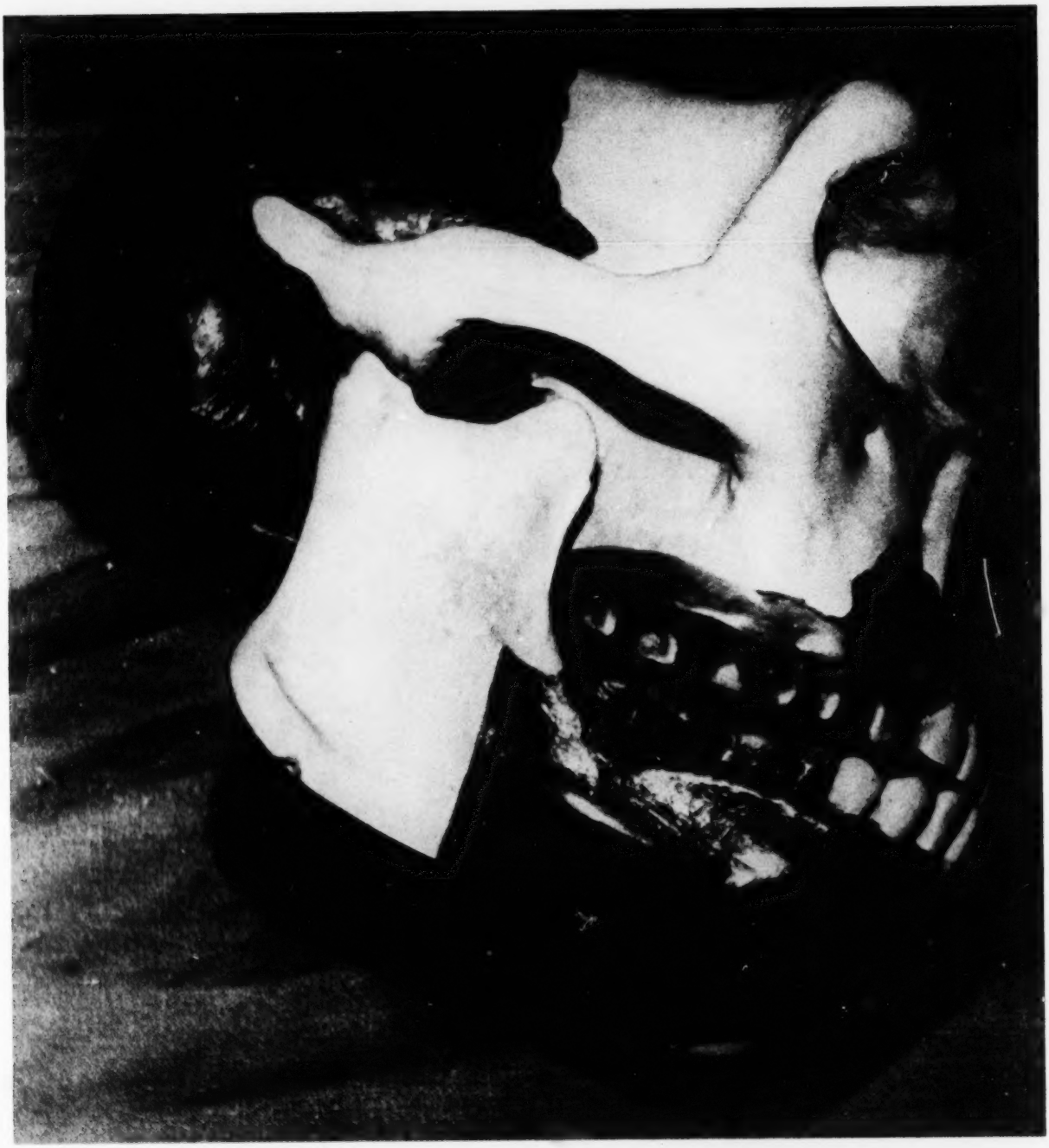

Figure 4.9b. *Photo of a skull of* Homo erectus *(courtesy of Carolina Biological Supply, Burlington, N.C.).*

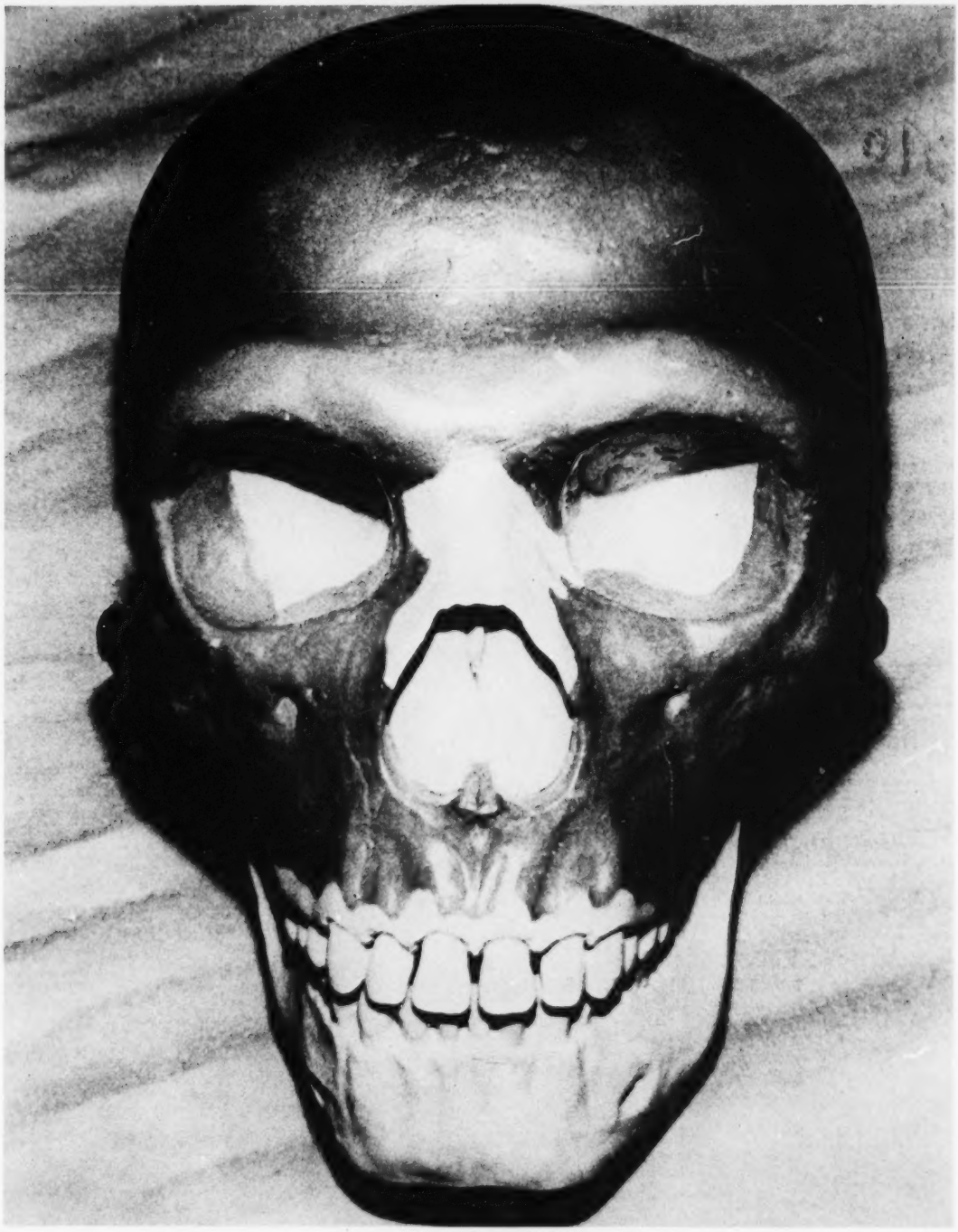

Figure 4.9c. *Photo of a skull of* Homo sapiens neanderthalensis *(courtesy of Carolina Biological Supply, Burlington, N.C.).*

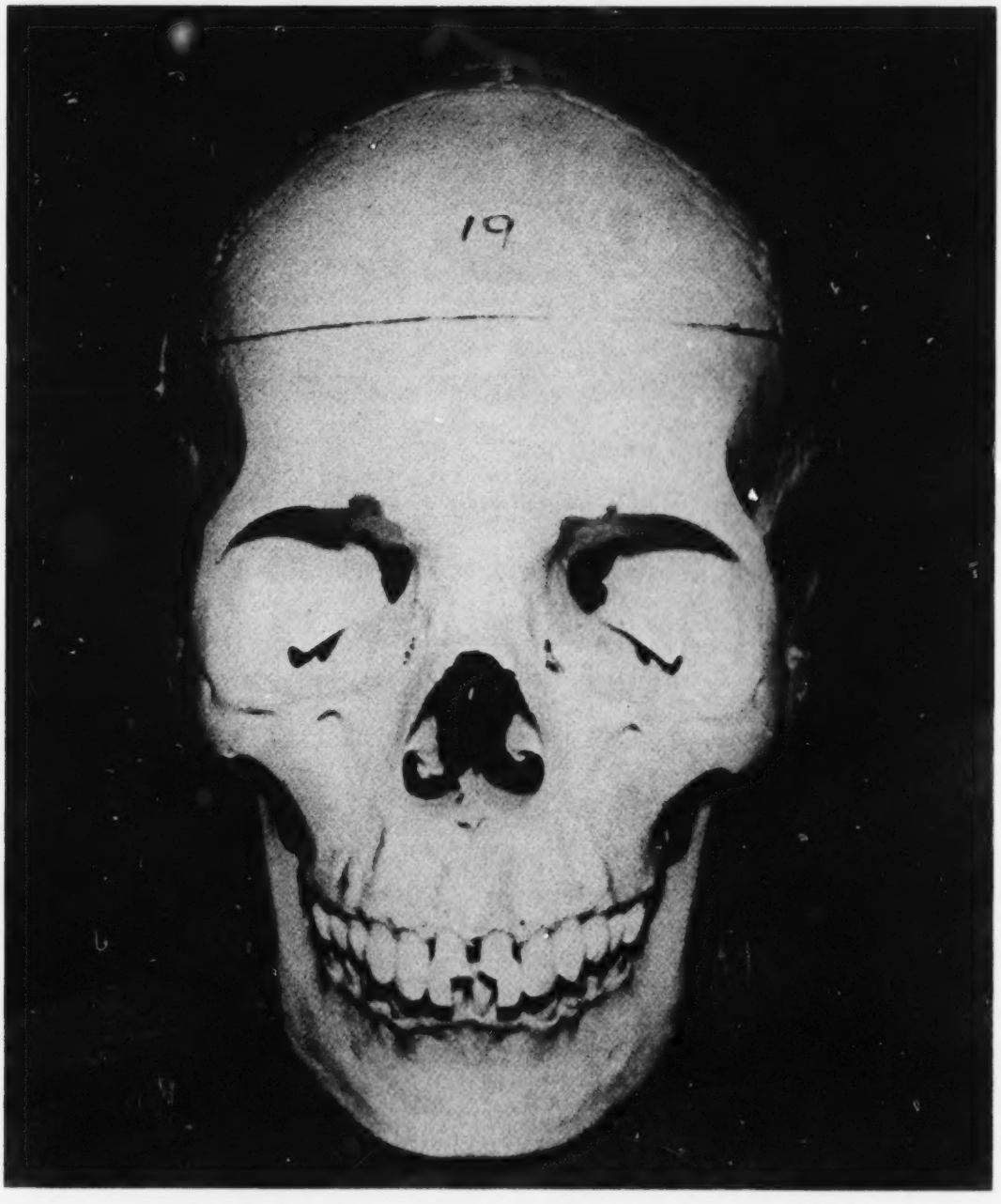

Figure 4.9d. *Photo of a skull of* Homo sapiens sapiens *(courtesy of Carolina Biological Supply, Burlington, N.C.).*

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The patterns typically recognized by students are changes in jaw and cranial size and facial sloping. Less dramatic changes that can be brought to students' attention are changes in dentation, loss of jaw protrusion, increase in frontal bones, and reduction in orbits.

After students have guessed the progression of skulls, provide the names and dates of the types of humans represented by the skulls.

Skull Type	Date
Australopithecus	1.70 million years ago
Homo erectus	.50 million years ago
Homo sapiens neanderthalensis	.05 million years ago
Homo sapiens sapiens	Present
What's next?	The future

Risk your ideas. What's next? Invite students to risk ideas about the future. Challenge them to predict what appearance the human skull will have one million years from now. Have students write about, sketch, or sculpt in clay the next human skull. Ask them to share their creations with others. Students enjoy the challenge of making predictions and often represent the future with E.T.-like skulls that have large braincases, and narrow faces and jaws.

Show How to Know

Looking into the future of human evolution is often like blazing a trail. It is exhilarating but at the same time frightening. It requires an architect's imagination, a gambler's daring, and a general's ability to plan. Helpful to knowing where we are going is knowing where we've been. Our rear-view mirror to human evolution is a book written over one hundred years ago by Charles Darwin, called *On the Origin of Species by Means of Natural Selection.* This revolutionary book about evolution changed our lives and the way we look at ourselves. Evolution, which simply means "change," explains how we are quite different from our ancestors who lived thousands of years ago.

A plan of action will permit students to make educated guesses instead of "eyeballing it." Using jaw size as an example, show how to make predictions. Reconstruct the past jaw size, look for a trend, and then, extend the trend into the future. Once the model for predicting jaw size has been provided, the students can be turned loose to explore other features of the skull. These may include cranial capacity, facial width, facial sloping, brow ridge, and orbit diameter.

Reconstruct the past. Where can clues to events that happened thousands of years ago be found? New approaches to investigating the nature of prehistoric humans show great promise. Descriptions of dietary habits are etched in the hard parts of humans—teeth and bones. The same structures reveal tell-tale signs of stress and disease. Weapons used by humans thousands of years ago to kill game still contain well-preserved blood. Even DNA can be extracted from fossils! Using sophisticated chemical techniques on blood samples, scientists have identified species (including humans). And the paintings, drawings, and sculptures left behind are clues to life in earlier times.

What has happened in the last two million years to nutrition and dietary habits? This may be answered in part by comparing the jaw size of our ancestors to present-day skulls. Follow instructions on page 94 for taking jaw measurements. Record these as a percentage of head height (jaw index). Self-measurements can be taken to get data representative of the present; take the average of a class.

Species	Jaw Ht.	Head Ht.	Jaw Index or Percent Jaw of Head
Australopithecus	8.5 mm	15 mm	56.6
Homo erectus	8.0 mm	16 mm	50.0
Homo sapiens neanderthalensis	6.5 mm	19 mm	34.2
Homo sapiens sapiens	5.0 mm	17.5 mm	28.5

Search for a pattern. Describe the changes, if any, in jaw size over the past two million years. To recognize a trend, you will need to graph the data for jaw size. Is there a change? Is the jaw size decreasing or increasing? Try to interpret what these changes mean.

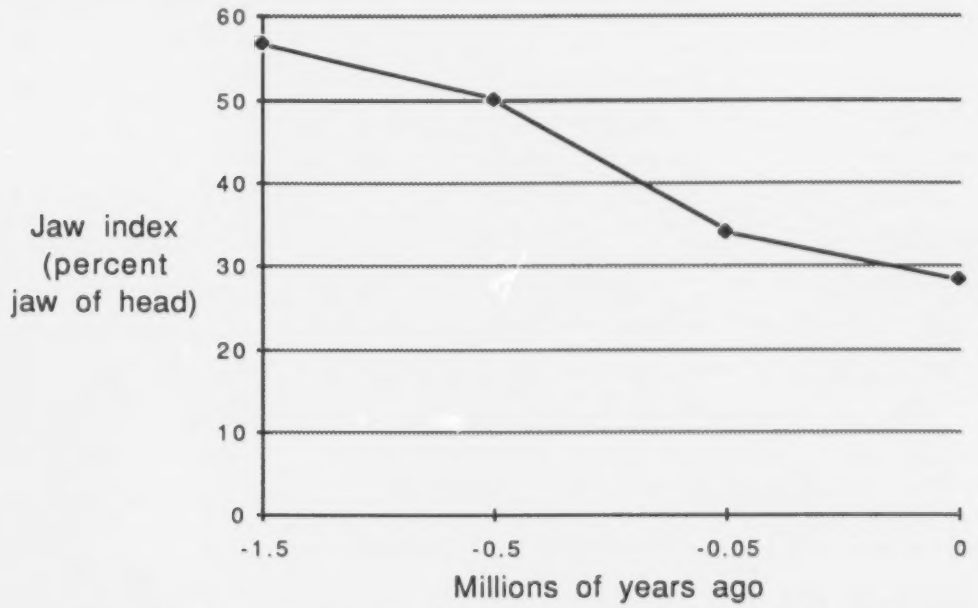

Figure 4.10. *Changes in jaw index (percent jaw of head) recorded over 1.5 million years.*

Predict the future. Based on the reconstruction of the jaw and its changes traced through history, develop a way of predicting the size of the jaw in the future. Make an "if . . . then" statement. For example, if the size of the human jaw has become smaller or larger over the past two million years, then future jaw size will . . .?

Predictions of the future can be made by extrapolation or extending the curve (trend) constructed on the graph. Simply put a ruler over the curve relating jaw size to time. Extend the curve to a future time, for instance, half a million years from now. Read the jaw size predicted from the graph. Interpret what these changes will mean for individuals living in the future.

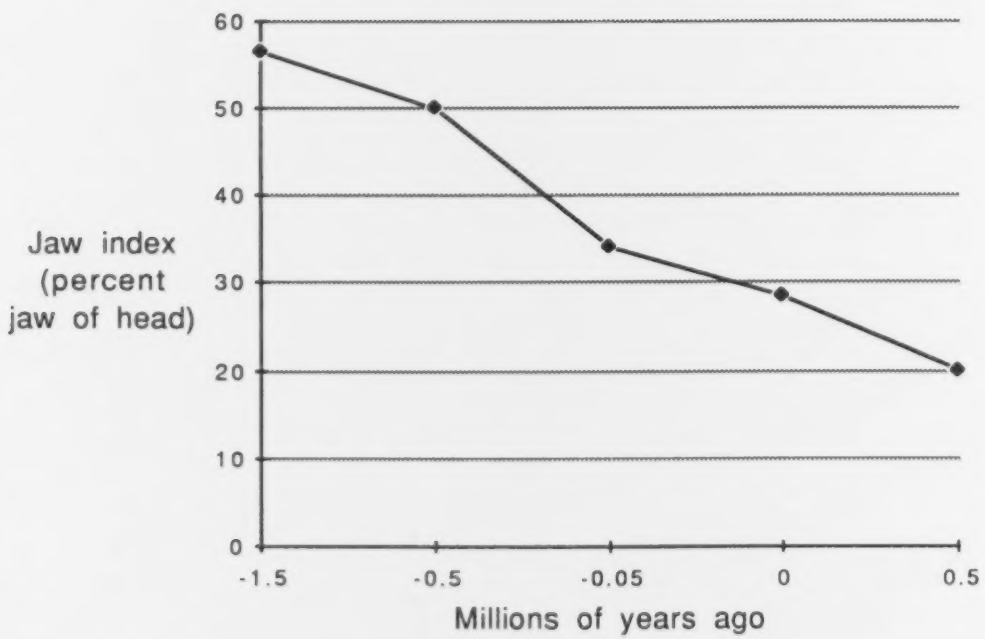

Figure 4.11. *To predict future jaw size, extend the curve to 0.5 million years from now.*

Apply Know-How

Once students understand how to take measurements, graph the measurements, and extrapolate to the future, you can turn them loose to explore other features of the skull. Examples of features they might choose include the following:

- Facial width
- Cranial capacity
- Brow ridge
- Orbit diameter
- Jaw protrusion
- Frontal bones
- Molar and canine size
- Orbits

Working as teams, students can construct their chosen feature out of clay. A composite skull of all the features can then be created. Each team's prediction, put together with the others, forms a human skull for the year one million. Shown here is a photo of a composite clay skull constructed by teams of seventh- and eighth-grade students.

Read what others have predicted about the future. Be critical. Compare your predictions with theirs. Would you classify yours as wild guesses or educated predictions? What separates the two?

Future 4.12. *A clay model of a skull constructed by a team of young students that represents their prediction of "what's next."*

Know How to Inspire Cooperation

Besides encouraging creativity, forecasting human evolution has practical applications. Among those anxious for answers about the future are those whose jobs require planning for business, government, and the health-care industry. Here are examples of questions whose answers would be valuable to know:

- ☞ Will diets change significantly?
- ☞ What diseases will our descendents have?
- ☞ What will be the average lifespan?
- ☞ Will our heirs be shorter or taller than we are?
- ☞ Will muscles become larger or smaller than ours?
- ☞ Will the cranial capacity of our descendents be higher or lower?
- ☞ Will health be better or worse?

Group students according to questions that most interest them. Coach students to put together a plan of their own in writing for predicting the future. Suggest how they can practice division of labor. If they need direction, encourage them to piggyback on ideas presented by the model.

Encourage students to brainstorm ideas about the future. What do they guess about the future of our health or lifespan or height? Record all student guesses. Follow the rules for brainstorming:

- **Say everything that comes to mind.**
- **Do not judge any ideas.**
- **Don't discuss anything.**
- **Repetition is okay.**
- **Piggybacking on others' ideas is encouraged.**
- **Accept and enjoy moments of silence; often a new burst of ideas follows.**

No one has a crystal ball to see the future. Nevertheless, educated guesses can be made according to the model with a high degree of confidence. Give students fifteen minutes to write a plan for making an educated guess. Reiterate to students that making educated guesses about what's next in human evolution is a three-step procedure:

- Reconstruct the past.
- Search for a pattern.
- Make predictions based on a pattern.

More clues to the past. Some of the best-known scientific treasures of the past are buried with Egyptian mummies. Remarkably, many of them have been preserved for more than two thousand years, and autopsies have been performed on thousands of them. In addition to the history that their bones record, mummies hold secrets about our ancestors' health, stature, technology, longevity, and so on.

To unlock secrets of the mummies, experts in different specialities are needed. Anthropologists, art curators, historians, physicians, toxicologists, and others working in teams can identify patterns that an individual working alone would probably overlook. By comparing life reconstructed from the past to present-day living, students can search for trends.

Following is a example if the type of project students might try as another way to reconstruct the past.

General examination (read aloud): *Most of these observations were made during an autopsy of a mummy done in 1975. Twelve layers of linen wrapped the mummy. The body was covered with a resin of some sort, which was probably hot when poured. The limbs and fingers, as well the body, had been wrapped. When unwrapped, the arms were crossed.*

The skin, light brown in color, was hard as plastic and had to be dissected with a saw. Inside, packages containing the heart, lungs, and other organs were found. The body cavity contained resin. The brain was missing, probably removed through a hole at the bottom of the skull. The eyes were still intact and well preserved. The nails had been painted red with henna and the feet were painted white. The body—more than two thousand years old—was remarkably well preserved. Some of the observations that were made during the autopsy are exhibited (or described) here.

Note: These exhibits (or descriptions) can be the starting place for students to reconstruct the past. Assign exhibits to individual or groups of students to research. From their research, a great amount of information about the lives of these ancient Egyptians can be guessed.

Exhibit A: Abnormal thickening and porosity of skull bones suggest the occurrence of an anemic blood condition. A study of modern-day Nile dwellers shows that blood anemia is caused by inborn genetic errors, iron deficiency, or infestation of the schistosome parasite. Research the symptoms and causes of anemia to reconstruct the state of health of this person more than two thousand years ago.

Exhibit B: Fibers of cotton found clinging to body wraps. This is the earliest find to date of cotton in the European and Middle Eastern areas, raising questions about possible trade routes between Egypt and India, where cotton was known to be cultivated. Research growing conditions and the manufacturing of cotton to reconstruct early agriculture and commerce.

Exhibit C: Arteries, some with plaques of fat on the walls. Research arteriosclerosis to reconstruct life-styles and health practices. Whatever the cause, it appears that arteriosclerosis is an ancient disease.

Exhibit D: Lung tissue (alveoli) scarred with carbon and silicon dioxide particles. Carbon itself is not toxic unless accompanied by silicon. Today, inhalation of silicon is common in miners, quarry workers, and potters. Research the causes and symptoms of the lung disease silicosis to reconstruct life-styles and health practices.

Exhibit E: Bone with measurable levels of lead and mercury. The mercury level is about the same as that measured in modern bones. Research the effects of chemical pollution by lead and mercury to reconstruct life-style and health practices.

Exhibit F: The parasitic worm Ascaris is found in the intestine. Because this worm commonly infects pigs, it offers clues about the person's nutrition. Research the causes and effects of this worm infection to reconstruct nutrition and health practices.

Exhibit G: Microscopic animal lice found attached to skin in hairy regions. These have been discovered in about one-quarter of the mummies examined. Research hair and body infections to reconstruct life-style and health practices.

Exhibit H: When viewed under a microscope with ultraviolet light, cross-sections of bone glowed a bright yellow-green. This is a diagnostic test for the presence of the drug tetracycline. It suggests that this broad-spectrum antibiotic was used unwittingly, perhaps due to moldlike bacteria that contaminated grains. Research the use of tetracycline in medicine and its sources then and now.

Exhibit I: Body well preserved, lifelike after two thousand years. Research the techniques of preservation to reconstruct the technology and burial techniques.

Exhibit J: Writings and graphics adorning casket of body. Research how hieroglyphics can be used to reconstruct life-style and technology.

Exhibit K: Clay particles found in the stomach. Because of its ability to absorb gases and fluids, clay, perhaps, had therapeutic functions. Research the therapeutic function of clay to reconstruct health practices.

Summarize this section by reminding students that making predictions can be risky but also challenging and fun. By learning the rules, students will become confident of making predictions. Encourage them to apply the techniques they have learned to other areas in which they are interested. Coach them to be creative problem solvers.

5 Experiment! Experiment!

Predictions are educated hunches or guesses. The validity of hunches must be tested through experimentation. Predictions that are accepted without evidence can lead to erroneous beliefs. For more than two thousand years, it was believed that heavier objects fall faster than lighter ones. This belief was based on an untested prediction made by Aristotle. Galileo was the first to test the validity of Aristotle's prediction. Through experimentation, he proved that all objects, from boccie balls to marbles, fall at the same rate. The danger of jumping to conclusions without evidence is illustrated by this as well as other predictions made by Aristotle about the human body, earth, and matter. When his predictions were proved erroneous, scientific thinking was revolutionized and advances were made in astronomy, biology, and physics.

The logic used in science is no different from that used in the everyday world. But the power of the mind alone cannot be relied upon to solve problems. Evidence to support or refute predictions must be accrued through experimentation.

Skills	Activities	Materials
Developing experimental skills	What Is the Best Cookie?	Three different kinds of cookies
Applying experimental skills to problem solving	What Is the Right Stuff?	Balance Beakers Tape measures Graph paper Cardboard box Twelve-inch ruler Knives

The chapter begins with a fun exercise in which students develop ways of testing predictions about their favorite cookie. By creating an environment that encourages risk taking and charging students to carry out an experiment of their own creation, skills of experimentation are developed. The skills are applied to solving a problem about human performance, "What Is the Right Stuff?"

Many beliefs about athletic performance are untested. Until experiments were done, it was believed that drinking water before or during an event was harmful; salt pills were needed by athletes who worked up a good sweat; and athletes who were muscle-bound were inflexible. Before scientific methods were applied to sports, prospective athletes were drafted by professional teams on the strength of hunches made by scouts. Now, professional sport teams test athletes to select and match them to the appropriate positions. Factors such as weight, physique, strength, agility, and motor ability are weighed in the equation for the right stuff.

The human performance problem called What Is the Right Stuff? draws a number of different sciences together to model how to solve a real question about human performance. Information from anatomy, biomechanics, psychology, statistics, and physiology is used to identify the characteristics important to athletics. Using themselves as subjects, students make observations of speed, agility, strength, and endurance. Based on patterns found between performance and body traits, students predict the stuff that's right for performance.

Predictions are tested by correlating physical and physiological traits with performance. Measurements of body size, limb volume, ventilation, and circulation are matched to speed trials, agility times, strength tests, and endurance records. High correlations between body measures and performance help identify those measures that are the right stuff for performance. Students can piggyback on ideas presented in this unit to develop their own plan for exploring performance.

What Is the Best Cookie?

Goal. To encourage students to formulate predictions and develop ways of testing their predictions.

Props. Three different kinds of cookies (for example, chocolate chip, cream-filled, and cinnamon graham), balance, beakers, magnet, probes, rulers, knives.

Introduction. Most students are uncomfortable making predictions and designing solutions to problems. By creating an environment that encourages risk taking and using an activity that is enjoyable, students are motivated to be creative. Students recognize that they can learn from making wrong predictions as well as right ones. Many discoveries in science, in fact, have originated from incorrect predictions.

The rules.

- The leader tells students that they have been asked by the laboratories of *Consumer Reports* to scientifically determine the best cookie from the three samples present. Students are then asked what it means to scientifically determine the best cookie. Working in teams, students predict which cookie is the best and what tests to perform to prove or disprove their prediction.
- Students are given three cookies each. Using the apparatus available, students test their predictions. Only a minimum of resources is needed; in fact, the more limited the resources, the more creative students become. Some of the tests might include tasting, crumbling to determine texture, burning to test for plastics, weighing, measuring the dimensions and density, and examining the ingredients on the package.
- After thirty minutes, students tabulate results on the board. Suggest that for each test performed, students rank the cookies 1, 2, and 3. Based on the ratings, students conclude which cookie is best.

Processing the activity.

☞ Ask students to compare predictions with conclusions. Do they agree?

Note: Often predictions and conclusions do not agree. Students' predictions about "best" are usually based on subjective reasons (such as what they remember from commercials) instead of objective ones. Only through collecting data about taste, texture, size, and smell, and comparing data to standards or controls, can objective decisions be made about what's best. From reasoning in hindsight, students discover the value of the scientific method for making predictions, collecting data, using controls, and making conclusions.

☞ What could be learned from making the wrong prediction?

☞ Were the experiments controlled? Were there standards to which their results could be compared?

☞ What additional tests might be done? What can be learned from mistakes to prevent future ones?

Real-world examples. Here are some famous beliefs that were based on untested predictions. Using the names provided, ask students to research the alternate hypothesis and the experimental evidence for it. The first one is given as an example.

Health: For a over a century, it was believed that fever was harmful to health. Aspirin was routinely recommended to "break" the fever. Research the work of Matthew Kluger.

In an elegant experiment conducted by Kluger with iguanas, it was shown that fever acts as an effective ally against infection. Iguanas were infected with a bacteria known to cause illness in reptiles. Like most animals, iguanas developed a fever in response to the infection. When iguanas in an experimental group were given a fever-suppressing drug, more than half died from the infection. Of those animals able to raise their body temperatures, all but one survived the infection. The results helped reverse the approach now taken to control fever in humans. Fever is now viewed as protective instead of harmful to health.

Astronomy: Until the 1500s, Earth was thought to be the center of the universe. According to Aristotle, the sun, moon, planets, and stars all orbited around Earth. Research the work of Copernicus and Galileo.

Biology: Until the eighteenth century, people believed in spontaneous generation; manure piles gave rise to worms and garbage to maggots. Research the contributions of Pasteur, Redi, and Spallanzani.

Geology: Until this century and as recently as the 1960s, it was believed that Earth's surface was very rigid and the land masses were permanently separated; the Earth's surface was shaped suddenly by catastrophic events (the great flood in Noah's time). Research Alfred Wegener's work.

Chemistry: Until the late 1700s, it was believed that matter, such as a log, could be destroyed by burning. Research Antoine Lavoisier's work.

Health: About a century ago, it was accepted that evil spirits, bad air, and miasmas, arising from refuse heaps, were the cause of diseases such as tuberculosis and anthrax. Research the contributions of Robert Koch.

Create a Need to Know: Human Performance

Where do you fit? Do you feel physical fitness is something for others to work at, or is it as important to you as spiritual and mental fitness? Most students understand they fall somewhere between a "couch potato" and an "iron man," but identifying where they fall on the fitness continuum between the two extremes is difficult.

Couch Potato ——————————————————Iron Man

Classroom Calisthenics is an ideal way for students to test their own fitness and become actively involved in the scientific study of human performance. Only minimal space and equipment are required to create stations for the calisthenics in the classroom. Organize the class into teams. Each team completes each station at its own pace; a different person of the team must volunteer for each new station. The team that scores the most points is declared the **most fit**. Some examples of stations and instructions for operating them are the following:

What is your leg strength? Strength is the ability of the body to exert force on its surroundings. The body's muscles, acting to move the bones, generate force. The important muscles are those of the legs, arms, and trunk. Great leg strength permits Superman to leap tall buildings and stop speeding trains! For the average human, leg strength is used in lifting objects, walking, and standing erect. For the athlete, leg strength is important in sports such as football, soccer, basketball, and hockey.

Strength can be measured with only minimal equipment and space. Leg strength can be measured by either the standing broad jump or standing vertical jump. For the broad jump, subjects jump horizontally from a standing position (arms must remain motionless). The distance jumped is proportional to leg strength. Record the distance in centimeters (using a tape attached to the floor) as your score for leg strength.

What is your body flexibility? Flexibility—how limber you are—encompasses the ability to move a joint through its normal range of motion. To get out of bed in the morning or tie your shoes, for example, you need some flexibity in the trunk, hips, and knees. What sports require good flexibility?

Place a box on the floor against a wall. Tape a ruler so that the 10 cm mark lines up with the near edge of the box and the 30 cm mark is farthest from you. Sit on the floor with your legs extended so that your heels are about five inches apart and your feet flat against the box. Slowly reach with both hands in front of you. Touch the ruler and record the distance you have traveled. Your score for flexibility is the number of centimeters you have reached.

What is your arm and shoulder endurance? You use endurance when you carry books home or stand upright for long periods. A sign of low muscular endurance is muscle soreness. If you suffer for a couple of days after rowing or hiking, you need to improve your muscular endurance. Sports such as swimming, lacrosse, and long-distance running require endurance training.

Push-ups are used to measure endurance of the shoulders and arms. The number of push-ups that can be done in a certain time period is a way of measuring this strength. A modified push-up, using the wall instead of the floor, is ideal for the classroom. Stand arm's length from the wall. Lean into the wall with back straight to begin the first push-up. Count the number that can be done in sixty seconds and record that as your endurance score.

How fast are you? Speed is rate of movement measured by the time it takes to cover a certain distance (meters/minute). Your own level of speed fitness is shaped by your routine—the classes you have, sports interests, and the daily rush to classes, jobs, etc.

The only equipment needed to measure speed is a tape measure and stopwatch. Using the tape, measure a distance appropriate to the classroom: 10, 20, 30, or 40 meters. For each trial, have the runner assume a comfortable starting position behind the starting line. From the starter's mark, record the time to cross the finish line. Divide the distance covered by the time in seconds. This is your speed score expressed in meters/second.

What is your agility? Agility is the ability to change directions rapidly and accurately. In sports such as skating and basketball, agility is important to performance. The course used for speed trials can be reused for testing agility. At the edge of the course opposite the starting mark, place a bottle. A runner must complete the agility course by running the length of the speed course, changing directions by running around the bottle twice, and then returning to the finish line. Divide the distance covered (twice the speed course) by the time in seconds. This is your agility score in meters/second.

What is your team's total score? The team fitness score is calculated by adding the individual scores.

Your score for leg strength is _____cm.

Your score for flexibility is _____cm.

Your score for endurance is _____push-ups per 60 seconds.

Your score for speed is _____meters per second.

Your score for agility is _____meters per second.

Total _____

Total the scores and compare the team scores for a measure of fitness. The higher the score, the more fit the team. Which team has the fitness of a couch potato? An iron man?

Challenge to Know: The Right Stuff

The challenge. For centuries, dating back to the early Greeks, scientists have pondered the right stuff for strength, speed, endurance, and flexibility. It was once believed, for example, that hair length and body strength were directly related; it was thought that a loss of hair (haircut) would cause a loss of strength. Today, exercise physiologists, biomechanists, and others look for answers to: What is the right stuff? by studying the anatomy, physiology, and psychology of humans. This question is still not satisfactorily answered.

Risk your ideas. Use strength as an example. Brainstorm ingredients that might be important to strength. For instance, try to recall from your own experience what connection exists between strength and stature, weight, leg volume, and other traits. The longer the list, the better. Follow the rules for brainstorming. Here are some students' guesses.

Ingredients in the right stuff for leg strength

Pelvic width
Flexibility of knees
Circumference of legs
Upper leg length
Leg volume
Body weight
Body height
Age
Training

Devise a way to rank the ingredients from most to least important.

Show How to Know

A plan of action. A plan that permits you to successfully judge the most important ingredients for performance uses the scientific method. The plan begins with making observations of strength. Patterns that exist between strength and body differences are noted. Based on apparent patterns, predictions about the right stuff can be made. Predictions are confirmed or refuted by collecting data and testing predictions. Conclusions about the nature of the right stuff for performance can then be made.

Make observations. Observations of leg strength can be made by using the following test. Make a starting line on the floor with chalk or tape. From a standing position, participants broad jump. Mark the distance from the starting line to where the heels land on the floor. Take the average of two jumps. The distance jumped is proportional to leg strength. Recruit at least eight subjects to test; the more (up to twelve subjects), the better. Record all data on a score sheet.

Look for patterns. Look for patterns between performance and the performer's physical or physiological traits (body size, length of limb, knee flexibility, sex, etc.). Do these patterns confirm guesses risked earlier about the right stuff for performance?

Subject	Distance in cm (Leg strength)
Gail	100
Ron	156
Jane	98
Dave	175

Make predictions. Review earlier guesses. Based on patterns seen, add or delete from the brainstorm list. Now that you are better educated through testing performance, select five or six measures from the list on which to focus. In the real world, there are always limits to the resources you have: time, money, labor. Because of limits to resources, only a few of the measures can be made. Work together to compromise differences.

Predict which ingredient is most important to strength performance and which are second and third most important. Record these predictions in the appropriate column on your score sheet.

Collect data. Make measurements of human physical, physiological, or psychological traits. The science that deals with the measurement of physical traits is called anthropometry. Exercise physiology is a "movement science" that measures physiological traits of performance. Sports psychology measures the influence of the mind over the body. Together these sciences set standards for measuring body circumference, volumes, diameter, lengths, and masses, along with lung volume, heart rate, mental attitude, reaction speed, balance, and so on.

These measures, along with others you may have selected, are the variables to which human performance (leg strength) will be correlated. Instructions for taking some of the more common measurements follow.

Anthropometric measurements. The more data that is gathered, the more significant will be the results. Perform each measure two times and take the average of the two. If the second measure deviates widely from the first, take a third measure. Record the average measure on the score sheet.

Height.

Equipment: Tape measure.

Procedures: All heights either for the whole body or body part should be made along the longitudinal axis while standing. Take all measures without shoes. The subject should stand erect with the head facing forward.

Place a flat surface (for example, a ruler) on the top of the skull. Measure the distance between the skull (ruler) and the floor.

Weight.

Equipment: Balance.

Procedures: Take weight measures without shoes. Record weights in kilograms to the nearest 0.1 kg or in pounds to the nearest pound.

Circumference.

Equipment: Tape measure.

Procedures: The amount of tension applied to the tape measure is the single largest variable in making accurate body measurements. Try to use the same tension for each measure. Avoid stretching the tape so as to depress the skin surface. Make all measurements of muscle relaxed, lying on the horizontal plane.

- Neck: Measure an inch below the lower jaw or chin.
- Wrist: Measure at the smallest point of the wrist.
- Upper arm: Measure midway between the tip of the elbow and the top of the shoulder.
- Chest: This is taken at the nipple line (fifth rib). Maximally expand the chest.
- Hips: Measure at the widest level.
- Waist: Measure at the level of the navel.
- Thigh: Measure an inch below where the legs meet the buttocks.
- Calf: Measure midway between the ankle and the knee.
- Ankle: Measure at the smallest point of the ankle.

The more data that is collected, the more confident you can be of the results. Encourage students to volunteer to be subjects for the study. The following chart illustrates how data for circumference, weight, and height should be recorded along with the performance measure for strength.

Subject	Leg Strength (in centimeters)	Leg Circumference (in centimeters)	Body Height (in inches)	Body Weight (in pounds)
Gail	100	45	62	148
Ron	156	51	72	155
Jane	92	39	64	136
Dave	175	60	73	162

Graph data. After data for performance and body measurements have been collected from each subject, graph the data. Judge the relationships between leg strength and each body measure (anthropometric/physiological/psychological). At least three kinds of relationships may exist: positive, negative, or no relationship.

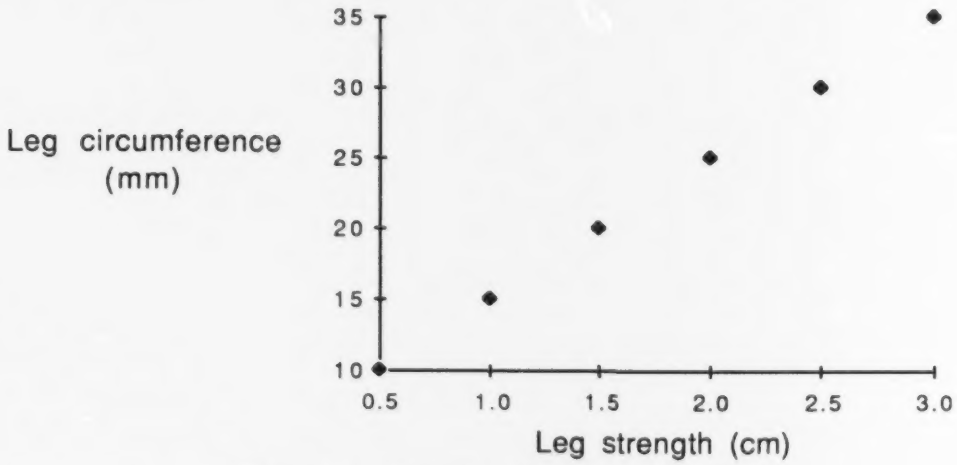

Figure 15.1. *Example of a positive relationship.*

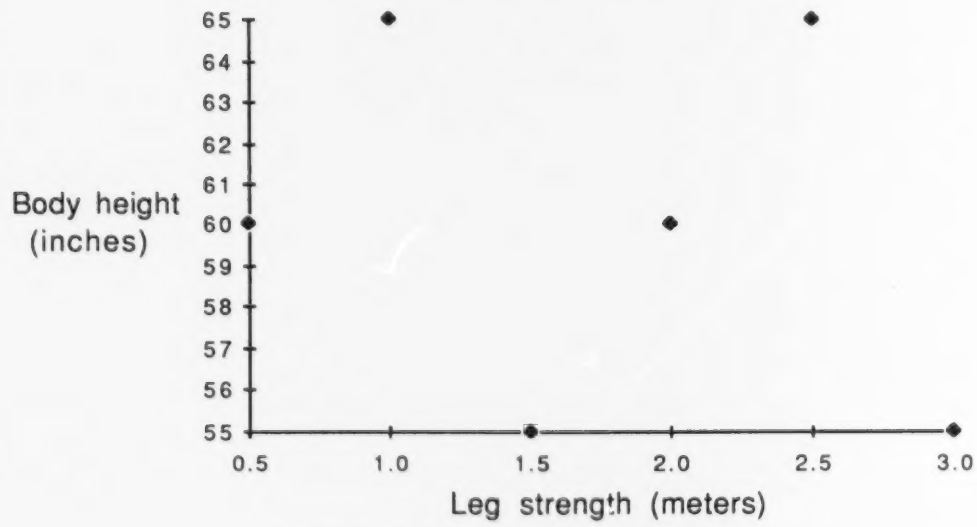

Figure 15.2. *Example of no relationship.*

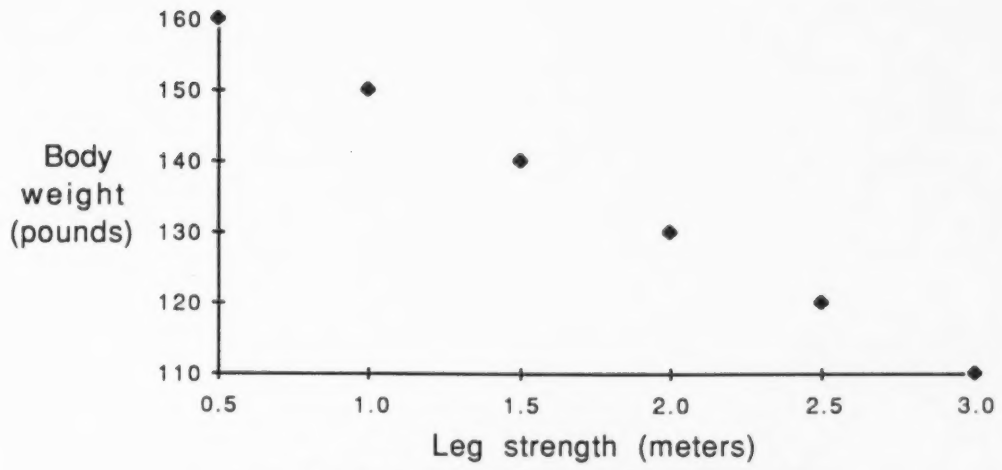

Figure 15.3. *Example of a negative relationship.*

The first graph (Figure 15.1.) shows a positive relationship between the two factors. As leg circumference increases, strength increases. No relationship exists between leg strength and body height, as shown in the second graph (Figure 15.2.). The third graph (Figure 15.3.) shows a negative relationship between the two factors; as strength increases, body weight declines.

Compute relationships. Both leg circumference and body weight are related to leg strength. A way of exploring the closeness of relationships between leg strength and either circumference or weight is by calculating the "correlation coefficient."

The coefficient, a number that measures the relationship between two factors, such as strength and circumference, can fall between +1 and -1. The closer the coefficient is to either plus or minus 1, the stronger the relationship between the body measure and performance. If the relationship is weak or nonexistent, the coefficient falls toward 0.

Correlation coefficients can be calculated by using the following steps. Because the procedure is lengthy, you may prefer to use a calculator or computer. (A sample program written for a computer in basic language can be found in Appendix 2.)

Computation of the Correlation Coefficent

Subject (4=N)	Performance Leg Strength		Factor Measured Leg Circumference		Product Stgth X Circum
	S	S^2	C	C^2	S X C (SC)
Gail	100	10000	45	2025	4500
Ron	156	24336	51	2601	7956
Jane	92	8464	39	1521	3588
Dave	175	30625	60	3600	10500
SUM	SS	SS^2	SC	SC^2	SSC
	523	73425	195	9747	26544

$$\text{Correlation coefficent} = \frac{(N)SSC - (SC \times SS)}{\sqrt{(N)(SC^2) - (SC)^2 \times (N)\,SS^2 - (SS)^2}}$$

$$= \frac{(4 \times 26544) - (195 \times 523)}{\sqrt{[(4 \times 9747) - 195^2] \times [(4 \times 73425) - 523^2]}}$$

$$= \frac{106{,}176 - 101{,}985}{\sqrt{(38988 - 38025) \times (293700 - 273529)}}$$

$$= \frac{4191}{\sqrt{963 \times 20171}}$$

$$= \frac{4191}{\sqrt{19424673}}$$

$$= \frac{4191}{4407}$$

Correlation coefficent = .95

Conclusions. What is the right stuff? The coefficients calculated for the first and third graphs are close to 1. If all the data points could be joined by a straight line, a perfect relationship would exist between strength and circumference or body weight. Graph 2 illustrates that no relationship exists between strength and body height.

The correlation coefficients computed between leg strength and each of the three factors follows. Rank the coefficients in order of those closest to 1 to those closest to 0 to determine the right stuff for strength.

Relationship	Correlation Coefficient	Right Stuff
Strength and circumference	.95	1
Strength and height	.05	3
Strength and weight	.82	2

The right stuff for strength is leg circumference. The measure least related to strength is body height. Body weight is also highly related to strength in a negative relationship.

Compare the results to the predictions. Greet the unexpected enthusiastically. Major advances in science are often fueled by discovering the importance of factors not previously thought to be significant.

Apply Know-How

Coaches could benefit. How can this information be used for practical purposes? Could athletes, coaches, or parents benefit from it? Knowing the right stuff for strength, speed, and other desired qualities, athletes could develop training programs targeted to increase performance. For instance, a program that focuses on increasing leg circumference will also increase leg strength.

Athletic coaches would be able to use objective criteria to draft players. For example, it has been suggested that particular individuals will excel in basketball because of their body size. Athletes with large muscle girths or small amounts of body fat may be sought by coaches of other sports. Selection criteria have been passed from coach to student over generations. Some criteria are well founded; others are not. Understanding the relationship between various body measurements and physical abilities offers a scientific way to separate useful criteria from irrelevant information.

Know How to Inspire Cooperation

Invite students to propose answers to questions about speed, agility, strength, endurance, and flexibility. Divide students into research groups. Ask groups to volunteer to study one area of performance, such as speed or flexibility. Charge each group to brainstorm the ingredients they consider important for that particular area of performance. Make a list (the longer the better). Follow the rules for brainstorming.

After about fifteen minutes, ask each group to share its ideas with their peers. Write each group's list on the board. Charge each group to develop a way of ranking the ingredients on its list from most important to least important. The new list creates its plan of action.

Developing a good plan—one that uses the scientific method—is the key to success. A good plan permits students to test their predictions. Ideas for how to proceed can come from studying solutions to problems related to theirs. For example, the previous study of leg strength is a good model. These steps were followed:

1. Brainstorm "stuff" important for performance.
2. Make observations of performance.
3. Look for patterns.
4. Make predictions.
5. Test predictions: make measurements, graph data, compute relationships.
6. Identify the right stuff.

Charge students to put together a plan of their own for studying performance. If they need direction, encourage them to piggyback on the plan used to study leg strength. Suggest that they practice division of labor. Who will organize taking measurements? Who will organize recording the data? Who will organize computing the data? Who will organize writing the results? Who will organize a search for literature on the topic? Who will take leadership for organizing the study? Get going!

This chapter examined only three factors believed to be important in leg strength; circumference, weight, and height. Other factors—anthropometric, physiological, psychological—could also be related to human performance. These include measurements of body diameters, volumes, lung capacity, fitness, reaction speed, behavior, balance, age, and sex. Students may choose to investigate some of these factors in their studies.

Sophisticated ways of making these kinds of measures in the laboratory already exist. The challenge is to adapt these methods to the classroom by creating procedures that are simple and require a minimum amount of equipment. Following are descriptions of measures likely to be useful for student investigations. These will require creating methods of testing to be used in the classroom.

- *Fitness level* is the measure of heart rate after a standardized step test.
- *Balance* is the ability to distribute weight evenly on both sides of a vertical axis.
- *Reaction time* is the time to respond to a visual or audio cue.
- *Lung volume* is the volume of air a person can expel after taking the deepest possible breath.
- *Limb volume* is the volume of water displaced by a hand, arm, leg, or foot.
- *Type A behavior* is behavior that is described as competitive, aggressive, and tenacious.

Before students begin testing, ask them to write a plan of action for evaluation. The success of their experiment will depend upon the quality of the plan, better known as the research proposal. The following steps summarize a way to organize the study.

1. Students submit a plan of action.
2. Students select subjects, score performance, and take measurements.
3. Students graph data, compute correlations, begin writing results.
4. Students explore existing literature to find out what others have written.

Ethical questions. Some of the ethical questions raised by competition deal with drugs to improve performance. Should athletes be allowed, for instance, to take human hormones to improve performance? Because of drug use, the International Amateur Association in 1981, banned Ben Plunkett, holder of the world record for the discus throw, from competition. The action made Plunkett the first American to be prohibited from competing in the Olympics as a result of positive tests for steroids. Since then, controversy over the pros and cons of using hormones to improve human performance has touched high schools, colleges, and professional sports.

Role playing is an ideal way to promote student participation in the controversy. Invite students to volunteer to become a panel representing the Amateur Athletic Federation, the world governing body of track and field. The panel will conduct a hearing to decide if athletes who take anabolic steroids should be banned from athletic competition. Other students will present pro and con arguments to the panel on banning athletes. Students could play the roles of coach, trainer, attorney, physician, and pharmacist. What are the arguments in favor? Against? Encourage students to research available literature and to interview athletes, coaches, physicians, and sports officials.

Part Three

IT'S YOUR TURN

6 It's Your Turn to Create

The earlier chapters illustrate how scientific inquiry can be taught using the model curriculum in a variety of ways. You can transfer this curriculum "as is" to the classroom, but you can also create a curriculum of your own based on the model. Your students' response to a program that is tailored to their interests, needs, and classroom environment can amply reward you for the time you spend creating your own curriculum. Following are tips for creating a personalized program and an example taken from a workshop for secondary teachers. Called "It Pays to Have Fun," the workshop prepares teachers to have as much fun as their students.

Where to Get Ideas

Ideas for topics. Consider which topics or areas could benefit from an inquiry approach. Some teachers might have a special area of interest. Others might choose a topic in which they have had little training; the inquiry approach would permit them to learn along with their students. Or perhaps the topic is one that is traditionally difficult to teach because it hasn't grabbed students' interest.

Ideally, areas of inquiry will involve an ongoing problem or controversy to which the answer is still unknown. Topics can be found in current magazines or newspapers. Many major newspapers, for example, feature a weekly science section. Real-world problems are preferred, but problems that students perceive as real and that require self-discovery fulfill the same need.

Ideas for learning objectives. What are your objectives? What do you expect your students to learn? The primary objective of A Nature-Nurture Mystery, for instance, is to introduce students to the roles that heredity and environment play in shaping the traits of organisms. Because most texts do not discuss the influence of genetics and environment together, this approach gives students the larger picture. There are other goals as well. After completing the unit, students will understand or have experienced the following:

- Experience the scientific approach. Understand the use and appreciate the value of the scientific approach to investigating problems. Because of the limitations to experimenting with humans, students will recognize that conclusions from studies in which humans are subjects are often tentative.

- Learn new scientific concepts. Learn the morphological and functional specializations of the brain and its parts and the relationship of handedness and sex to brain laterality. Understand how identical twins develop. Understand the transmission of genetic traits.

- Develop scientific skills. Learn how to construct family pedigrees, conduct interviews, make observations of behavior, and do historical research.

To summarize: Create a curriculum for your students by starting with these broad objectives: experience the inquiry approach, acquire new information, and develop new skills.

Rules to Follow

Create a need to know. Begin with an experience that stimulates curiosity and thus creates a need to know. Do something fun. Don't begin with a problem. Problem solving is hard work, something that students like to avoid or postpone. To grab students' interest, provide an experience that invites a question, that creates a need to know. Moreover, if the experience causes the student, rather than the teacher, to raise a question, the student will feel "ownership" of the problem.

Research of cognitive learning suggests that an important factor that influences learning is what the learner already knows. The difficult part is ascertaining what an entire class knows. There is often a wide range of differences in student knowledge. By creating a learning experience in which the entire class can participate, the teacher can be more confident of knowing where the class stands.

Requiring students to make observations and to look for patterns using themselves as subjects is a good way to introduce a problem. The nature-nurture question of human behavior, for example, begins with a survey of human laterality, using the students as subjects. The discovery of patterns from their own data (there are more right-handers than left-handers) invites questions about this human behavior. Learning about the right stuff for human performance begins with a survey of personal fitness that requires students to do a self-study of strength, speed, and so on. This first-hand experience invites questions about the cause of good performance, how it can be improved, and its application to sports.

To summarize: Create a need to know by developing an experience that grabs students' interests and is fun. Use data about humans to make observations and to look for patterns.

Get students to ask questions. If the introduction prompts students to ask questions, the first (and probably the largest) challenge to getting students to learn how to learn has been met. Philosopher John Dewey was one of the first to note that creativity evolves not from facts, theories, or hypotheses but from questions. The ability to formulate the right question is crucial to effective problem solving. Invite questions from students. Ask your own. Follow the rules of brainstorming: the longer the list of questions, the greater the chance of finding the best question to ask.

Among the questions to be asked is one that addresses your academic objective. This is the one for which you should prepare in advance. For example, after students make an inventory of laterality through a self-study, they might raise the question, What causes right- and left-handedness? This question can be anticipated. Showing students how to study the cause of handedness fulfills the objective of teaching students the roles nature and nuture play in shaping human traits. Other questions that students brainstorm can be the starting place for independent studies.

In summary: Develop a list of questions to ask. Anticipate the one that addresses your academic objective. Prepare for the question not by researching the answer, but by researching a strategy to answer the question. This strategy will serve as a model for solving this as well as other related questions.

Invite answers from students. Encourage students to "own" the problem by inviting them to guess the solution. When asked to predict the cause of handedness, for example, students might volunteer examples of how their own family or culture influenced their laterality. Making predictions develops personal interest in seeking answers to questions and encourages students to risk ideas of their own. Moreover, it creates a need to know how to solve the problem.

Show students how to know. Research shows that if you give young people rules and examples of their use, they can apply them to solving problems of their own. For example, once students understand the strategy of solving the nature-nurture mystery of human handedness, they easily apply this strategy to solving other nature-nurture mysteries. Developing confidence in the methods of inquiry produces significant improvement in students' formal reasoning. Moreover, they learn transferable skills that increase their academic aptitude.

According to Christopher Knapper, coauthor of *Lifelong Learning in Higher Education*, "We do a very good job of teaching kids how to solve problems for which we already know the answer. The challenge is to teach them strategies for tackling the problems we've yet to solve." The methods students learn for solving science problems include at least three: taking surveys, making correlations, and doing controlled experiments. It is popularly believed that controlled experiments are the only way to solve science problems. However, many scientists (such as cosmologists), hardly ever carry out experiments. Few of the solutions to the problems posed in *Coaching Science Stars*, in fact, are obtained through controlled experiments. Although controlled experiments give the most reliable results, they often require resources beyond what is available to students: special skills, equipment, and time.

Students, however, can arrive at solutions by making use of surveys or correlations. The nature-nuture mystery of human handedness, for example, required students to gather data from their families, friends, twins, art museums, etc., for relevant data. The solution to What and Where to Build is also discovered through surveys. The Right Stuff for Human Performance involves correlating performance with a number of physical, physiological, and psychological variables. And making predictions for What's Next in Human Evolution is accomplished by correlating changes in time to changes in the human skeleton.

Science is a process that requires a plan of action. As Carl Sagan has pointed out, science is a way of thinking, much more than it is a body of knowledge. If students are given a way of thinking, they can apply the rules with confidence, coming a step closer to taking control of their own learning. Model how to solve a problem. Give students a plan of action that is within reach of their abilities.

Coach students to be part of the solution. The idea of having students function as a group to produce a result has been carefully studied, and it works (Glassner 1987). If students are part of a team, they will feel as though they are part of the solution. In collaborative kinds of learning, each student has knowledge or a skill that can be used to help solve a problem. The role of the teacher is to organize students into groups and explain the rules of group dynamics: listen to each other's ideas, stay on task, involve everyone, share materials, encourage each other.

The division of labor that results from grouping students, sometimes called the "jigsaw model," permits each student to invest in the solution. To solve the nature-nurture mystery of human handedness, for example, each student can be assigned an area to research. Groups as well as individuals can practice division of labor. For instance, to solve the question about the right stuff for human performance, each group can be assigned a different performance to research and report.

The teacher can act as a coach or consultant, moving from team to team to give leadership, make suggestions, or offer encouragement. It may be necessary to motivate teams by setting up competition among them. The introduction to What to Build, in which student teams compete to create a winning design for a skyscraper, provides such an example.

Studies by psychologists show that the classroom arrangement can affect classroom participation. While studying student participation during brainstorming sessions before a writing assignment, it was found that students seated in a circle participated more in the discussion than students seated in clusters. Students placed in rows participated least. Within the classroom, groups should be arranged so that they can see and talk to each other. The room arrangement must underscore the need to share and work together. Along with reading material, other materials that students will need should be available.

In summary: Cheer students to become part of the solution. Organize them into groups. Offer them choices. Divide the responsibility for solving the problem; assign a different part to each group. Learn to coach students; listen to their concerns, offer advice and encouragement when they fail, and praise them when they succeed.

Real-World Experiences

Experiences that bridge the gap between the classroom and the world outside provide several benefits to the learner. They give firsthand experience with the topic being studied, real-world applications of knowledge, and the opportunity for self-discovery. These experiences offer credibility and relevance to classroom study (if someone besides the teacher says it's true, it must be true!). And they may introduce students to careers, perhaps some they have never considered.

Real-world resources are available even in the most spartan of environments: fields trips, guest speakers, debates. For the study of human handedness, for example, some experiences that can link the world outside to the classroom are the following:

- ☞ Survey other classes to gather data on laterality
- ☞ Survey own family to research family pedigree of handedness
- ☞ Interview identical twins
- ☞ Visit art museum to do historical research on laterality
- ☞ Interview foreign-born classmates to research cultural influences
- ☞ Research the influence of education on laterality through interviews with teachers and administrators
- ☞ Research newspaper articles for information on nature-nurture controversies
- ☞ Invite a genetic counselor to discuss the role of heredity with students
- ☞ Invite a counselor to discuss the cause of alcoholism with students
- ☞ Debate a nature-nurture controversy in class
- ☞ Invite a physician to discuss the roles of environment and heredity in disease
- ☞ Invite a criminologist to discuss the influence of home life and heredity on criminal behavior

How Can You Tell If It Works?

If answers to any of the following questions are yes, the curriculum you have created is working. This is feedback that students are developing self-confidence, taking control of their learning, are showing motivation to learn, and are becoming risk takers.

- Are students having fun? Do they appear motivated to learn?
- Do students take greater risks by volunteering, raising questions, sharing their views with others?
- Are students more confident problem solvers? Do they understand the strategy to solve problems? Can they transfer the strategy to similar kinds of problems?
- Do students perceive success or failure because of their own efforts? Are they self-reliant? Do they demonstrate interdependence and independence? Do they show greater responsibility, and ownership for learning?
- Do students ask about careers in science?

Feedback from observations. Susan chose to create a curriculum based on the model for meteorology to motivate her students to learn about the causes and conditions of weather through inquiry. Students were asked to create a contest to predict weather. With help from Susan, the rules of competition, awards, and objective were formulated by the students. The challenge was to accurately predict the next day's weather for one month. The person who made the greatest number of accurate predictions would be awarded the prize.

Before starting the contest, Susan showed the class how to read temperature, cloud formations, barometric conditions, wind direction, and wind speed. Observations were made daily and displayed for everyone to see. Once students understood how to make readings, they began to predict the next day's weather based on their own weather observations. Students were trusted to make forecasts independent of published ones. Those who had the greatest success were those who first learned to recognize a relationship between a repeating weather pattern and a weather condition. Understanding how weather patterns could be used to predict weather led to students' self-discovery of the rules of meteorology and weather forecasts. Susan built upon this self-discovery by leading students through a traditional lesson on meteorology. The lesson culminated with a field trip to a local weather station that included a conversation with a meteorologist.

Susan's students had fun both creating and participating in a contest to predict weather. Their role in designing the rules, creating the awards, and becoming players created a need to know about weather and its causes. The routine of making daily predictions encouraged risk taking, even in students who didn't normally volunteer in class. Students accepted more and more responsibility for making measurements, monitoring the predictions, and awarding the winners. And discovering on their own the knack of accurately forecasting weather gave students greater self-confidence. Following the field trip, one students even asked about a career in meteorology!

Feedback from surveys. The efficacy of a curriculum can also be measured objectively. Among the many tests that could be given is a test to measure locus of control. The Nowicki-Strickland Locus of Control Scale is designed for children in grades three through twelve; it is a forty-item, paper-and-pencil test with a yes-no response mode. The items sample a variety of situations (do you feel that you can change what might happen tomorrow by what you do today?) and persons (do you find it difficult to change a friend's mind?).

The results of the locus of control test tell researchers how students perceive success. Those students who feel that success (or failure) is based on their own efforts are described as internally oriented. Those who attribute luck, fate, or powerful others to their success (or failure) are described as externally oriented. Two decades of research show the positive relationship of academic performance, motivation, and persistence to internal orientation. Some researchers believe that a student's orientation has a stronger relationship to achievement than all other school factors. This kind of test was used to evaluate a summer enrichment program (Real-World Science) on which *Coaching Science Stars* is based.

Three years of surveys done before and after students completed the summer enrichment program showed that students became more internal. Compared to a control group of junior high school students matched in age and gender, the experimental group of students who had participated in the enrichment program became significantly more internal. Given that school achievement requires a degree of effort, the advantage of an internal orientation is clear; developing the persistence to succeed is more likely if students see a relationship between effort and outcome. A change to internal orientation is particularly significant for "at-risk" students who are reported to be more external than most.

In summary: Use observations of students—their motivation, involvement, self-confidence, risk taking, independence, and interdependence—to gather feedback about the curriculum. For a more objective evaluation, do an experiment; compare a control class to an experimental one that has learned through the curriculum you have created.

Teaching is more than managing information; it also involves knowing how to manage people. Teacher-coaches who succeed at both can develop the potential each student has to star in science. Coach students. Know how to develop winners.

Resource Materials

Coaching Science Stars can be adapted to a variety of teaching environments because the resource requirements are few. Except for the skeleton, the materials for the Play Book activities are inexpensive and readily available.

Chapter 2

World map
Periodic chart of the elements
Tape measures (cloth or plastic)
Jar tops of various sizes
Pocket mirrors

Chapter 3

Materials for building (toothpicks, used tennis balls, or any material that is readily available)
Drawing paper, protractors, rulers, knives (to cut material)
Foamboard, cardboard, or balsa wood

Chapter 4

Human skeleton (disarticulated)
Clay, graph paper, tape measures

Chapter 5

Three different kinds of cookies
Balance, beakers, knives
Tape measures, graph paper
Cardboard box, twelve-inch ruler

Computer Program to Compute the Correlation Coefficient for the Right Stuff

```
10  PRINT "*****************************************"
20  PRINT "*                                       *"
30  PRINT "* This program is designed to input    *"
40  PRINT "* data from two different tests and     *"
50  PRINT "* compute the correlation between the   *"
60  PRINT "* two sets of scores.                   *"
70  PRINT "*                                       *"
71  PRINT "*****************************************"
75  PRINT
80  PRINT "Enter the number of individuals who"
85  PRINT "are working in your group"
90  PRINT
95  INPUT N
100 PRINT
110 DIM N$(10)
115 PRINT "Enter the names of the individuals"
120 PRINT "who are working in your group. Be"
125 PRINT "sure to hit return after entering"
130 PRINT "Each name."
135 FOR I = 1 to N
136 PRINT
140 INPUT N$(I)
145 PRINT
150 PRINT "HI"; N$(I)
155 NEXT I
156 PRINT
160 PRINT "We must begin to input the data"
165 PRINT "From the first two tests!"
170 PRINT
175 PRINT "*****************************************"
180 PRINT "* If at any time you make a mistake *"
185 PRINT "* while typing in the data, do not     *"
190 PRINT "* worry, just type in either stop or    *"
195 PRINT "* quit and we will begin again!         *"
200 PRINT "*****************************************"
205 PRINT
210 PRINT "Please enter the name of the"
215 PRINT "Performance Measure!"
220 INPUT T1$
225 PRINT
226 PRINT "Please enter the name of the first"
227 PRINT  "Anthropometric measure!"
```

```
228 print
229 INPUT T2$
230 If T2$ = "STOP" or T2$ = "QUIT" then 226
235 PRINT
236 PRINT "Please enter the total number of"
237 PRINT "subjects tested!"
238 PRINT
239 INPUT S$
240 If S$ = "STOP" or S$ = "QUIT" then 236
241 PRINT
242 N1 = VAL (S$)
245 DIM T1(20):DIM T2(20)
246 DIM T3(20)
250 FOR I = 1 TO N1
255 PRINT "Please enter the score for subject #"; I
256 PRINT "ON"; T1$
257 PRINT
258 INPUT Z1$
259 IF Z1$ = "Stop" OR Z1$ = "Quit" THEN 250
260 T1(I) = VAL (Z1$): PRINT
261 PRINT "Please enter the score for subject #"; I
262 PRINT "On"; T2$
263 INPUT Z2$
264 IF Z2$ = "Stop" OR Z2$ = "Quit" THEN 250
265 T2(I) = VAL (Z2$)
266 PRINT
267 PRINT T1(I), T2(I)
268 PRINT
269 NEXT I
270 DIM E1(20): DIM E2(20)
271 DIM E3(20)
275 FOR I = 1 TO N1
280 C = C + T1(I)
285 D = D + T2(I)
290 E1(I) = T1(I) * T2(I)
295 F = F + E1(I)
300 E2(I) = T1(I) * T1(I)
305 G = G + E2(I)
310 E3(I) = T2(I) * T2(I)
315 H = H +E3(I)
320 NEXT I
325 I1 = N1 * F
330 I2 = C * D
335 I3 = I1 - I2
340 J1 = N1 * G:J2 = C * C
345 J3 = J1 - J2
350 K1= N1 * H:K2 = D * D
351 K3 = K1 - K2:L = J3 * K3
355 L3 = SQR (L)
```

```
356 R = I3/ L3
360 R = INT (R * 1000 + .5) / 1000
365 PRINT "The Correlation between"; T1$
366 PRINT "and"; T2$; "is"; R
370 PRINT
375 PRINT "Would you like to correlate another?"
380 PRINT "Anthropometric Measure with"; T1$
385 PRINT
386 INPUT A$
390 IF A$ = "No" THEN 1000
400 PRINT
410 DIM T3$ (10)
420 DIM R1 (10)
423 DIM P1 (20) : DIM P2(20)
425 PRINT "How many more anthropometric measures?"
426 PRINT "Would you like to correlate with": T1$
430 PRINT
413 INPUT N2
435 FOR I = 1 TO N2
436 PRINT "We will begin to enter the data"
437 PRINT "from the next test!"
438 PRINT
440 PRINT "****************************************"
442 PRINT "*                                      *"
444 PRINT "* Remember, if at any time you make *"
446 PRINT "* a mistake while typing in the data, *"
448 PRINT "* type stop or quit                   *"
450 PRINT "* and we will begin again.            *"
452 PRINT "*                                      *"
454 PRINT "****************************************"
455 PRINT
460 PRINT "Please enter the name of the next"
465 PRINT "Anthropometric Measure!"
470 PRINT
472 INPUT T3$ (I)
474 IF T3$(I) = "STOP" OR T3$(I) = "QUIT" THEN 455
475 PRINT
480 FOR M = 1 TO N1
485 PRINT
487 PRINT "Please enter the score for subject #"; M
489 PRINT "On"; T3$(I)
490 PRINT
492 INPUT Z3$
495 IF Z3$ = "Stop" OR Z3$ = "Quit" THEN 480
500 T3(M) ? VAL (Z#$)
505 NEXT M
510 D1 = 0:H1 = 0
520 FOR A = 1 TO N1
525 D1 = D1 + T3(A)
```

```
530 P1(A) = T3(A) * T3(A)
535 H1 = H1 + P1A
540 P2(A) = T3(A) * T1(A)
545 F1 = F1 + P2(A)
550 NEXT A
552 I1 = 0:I2 = 0
553 I3 = 0
555 I1 = N1 * F1:I2 = C * D1
560 I3 = I1 - I2
565 K1 = 0:K2 = 0
566 K3 = 0
570 K1 = N1 * H1
575 K2 = D1 * D1
580 K3 = K1- K2
585 L = 0:L3 = 0
590 L = J3 * K3
592 PRINT L
595 L3 = SQR (L)
600 R1 = I3/ L3
605 R1(I) = INT (R1 * 1000 + .5) / 1000
610 HOME
615 PRINT "The correlation between"; T1$
620 PRINT "and"; T3$ (I);"is"; R1(I)
630 NEXT I
1000 PRINT "Well";
1010 FOR I = 1 TO N
1020 PRINT N$(I); ", ";
1025 IF I = N-1 THEN PRINT "and";
1030 NEXT I
1035 PRINT "  "
1040 PRINT "It has been nice working with you!"
1045 PRINT "Hope you have accomplished all of"
1050 PRINT "your work.  In case you didn't record"
1055 PRINT "all of the correlations, here they are"
1060 PRINT "again"
1065 PRINT
1066 PRINT "The correlation between"; T1$
1075 PRINT "and"; T2$; "is"; R
1080 IF N2 = 0 THEN 1200
1085 FOR I = 1 TO N2
1090 PRINT
1100 PRINT "The correlation between"; T1$
1105 PRINT "and"; T3$ (I); "is"; R1(I)
1110 NEXT I
1200 PRINT
1205 PRINT
1210 PRINT "*********************************************"
1214 PRINT "*********************************************"
```

Bibliography

Annett, M. "Handedness in Families." *Annals of Human Genetics* 37 (1973): 93–105.

Armelagos, George. "Unwrapping the Mysteries of the Mummy." *Contact* (University of Massachusetts) 10, no. 3 (1985): 34–37.

Barsley, M. *The Other Hand: A Social History of Left-Handedness.* New York: Hawthorn, 1967.

Bever, Thomas G. "Cerebral Dominance in Musicians and Nonmusicians." *Science* 185 (1974): 537–39.

Blau, A. *The Master Hand.* New York: American Orthopsychiatric Association, 1946.

Borst, Richard. "Bring Your Skeleton to Life." *The Science Teacher* (April 1986): 42–46.

Breckler, Jennifer. "The Competitive Edge." *The Science Teacher* (December 1982): 28–37.

Browne, Malcolm. "Mummies Finally Yield Truth about the Pharaohs." *New York Times,* 6 December 1980, C1–2.

———. "Smithsonian Bones Reveal Tales of Suffering Long Ago." *New York Times,* 18 March 1986, C1, 7.

Bryant, Paul "Bear". *Notes Taken from a Coaching Clinic.* Montgomery, Ala.: University of Alabama, 1972.

Carnegie Council on Adolescent Development. *Turning Points: Preparing Youth for the 21st Century.* New York, 1989.

Carolina Biological Company. *Discoveries of Early Man.* Burlington, N.C., 1988.

Bibliography

Carter-Saltzman, Louise. "Biological and Sociocultural Effects on Handedness: Between Biological and Adoptive Families." *Science* 209 (1980): 1263–65.

Cioffi, J., et al. "Laterality of Stereognostic Accuracy of Children for Words, Shapes, and Bigrams: A Sex Difference for Bigrams." *Science* 204 (1979): 1432–34.

Clark, H. H. "Muscular Power of the Legs." *Physical Fitness Research Digest*, ser. 8, no. 2 (1978).

Clymer, Adam. "Children Remain Enthusiastic on Space Flight." *New York Times*, 2 February 1986, 1, 16.

Cockburn, Aidan. "Autopsy of an Egyptian Mummy." *Science* 28 (1975): 1155–60.

Collins, Robert. "When Left-Handed Mice Live in Right-Handed Worlds." *Science* 187 (1975): 181–84.

Coren, S., and C. Porac. "Fifty Centuries of Right-Handedness: The Historical Record." *Science* 198 (1977): 631-32.

Department of Environmental Management, Freshwater Wetlands Section. *Freshwater Wetland-Wildlife Evaluation Method.* Providence, R.I., 1985.

Deutch, D. "Pitch Memory: An Advantage for the Left-Handed." *Science* 19 (1978): 559–60.

Diamond, Jared. "The Great Leap Forward." *Discover* (May 1989): 50–60.

Diesterhaft, Kay, and Kathryn Gerken. "Self-Concept and Locus of Control As Related to Achievement of Junior High Students." *Journal of Psychoeducational Assessment* 1 (1983): 367–75.

Duke, Marshall, and Stephen Nowicki. "Locus of Control and Achievement—The Confirmation of a Theoretical Expectation." *The Journal of Psychology* 87 (1974): 263–67.

Ekman, Paul. "Asymmetry in Facial Expression." *Science* 209 (1980): 833–34.

Eldredge, Niles, and Ian Tattersall. "Future People." *Science* 83 (1983): 74–77.

Ettlinger, G. "Lateral Preference in the Monkey." *Nature* 204 (1964): 606.

Finch, G. "Chimpanzees' Handedness." *Science* 94 (1941): 117–18.

Galaburda, Albert, et al. "Right-Left Asymmetries in the Brain." *Science* 199 (1978): 852–56.

Geschwind, Norman. "Specializations of the Human Brain." *Scientific American* (September 1979): 20–25.

Giles, E., and J. S. Friedlaender. *Measures of Man; Osteobiography.* Cambridge, Mass.: Peabody Museum Press, 1976.

Goodman, Alan, and George J. Armelagos. "Disease and Death at Dr. Dickson's Mounds." *Natural History* 9 (1985): 12–18.

Gore, Rick. "The Dead Do Tell Tales at Vesuvius." *National Geographic* 165 (1984): 557–613.

Gur, Reuben, et al. "Differences in the Distribution of Gray and White Matter in the Human Cerebral Hemispheres." *Science* 207 (1980): 1226–28.

Haynes, Joyce. *Padihershef—the Egyptian Mummy.* Springfield, Mass.: George Walter Vincent Smith Art Museum, 1985.

Herron, J. "Cerebral Specialization, Writing Posture, and Motor Control of Writing in Left-Handers." *Science* 205 (1979): 1285–89.

Herron, Jeannine, ed. *Neuropsychology of Left-Handedness.* New York: Academic Press, 1980.

Hicks, Robert, et al. "Human Handedness: A Partial Cross-Fostering Study." *Science* 192 (1976): 908–10.

Bibliography

"Home of the Future Will Be Controlled by Computer." *Springfield Republican*, 12 November 1989, B7.

" Hooked Handedness and the Brain." *Science News* (16 October 1976): 247.

Huyghe, Patrick. "No Bone Unturned." *Discover* (December 1988): 39–45.

Jacobson, Willard, and Rodney Doran. "What Do Our Ninth Graders Think of Science and School?" *The Science Teacher* (May 1986): 59–61.

Johnson, David, and Roger T. Johnson. *Implementing Cooperative Learning in Structuring Cooperative Learning: Lesson Plans for Teachers*. Minneapolis, Minn.: Interaction Books Publications, 1984.

Johnson, Roger T., and David W. Johnson. "How Can We Put Cooperative Learning Into Practice?" *The Science Teacher* (September 1987): 46–48.

Jordan, H. E. "Hereditary Left-Handedness with a Note on Twinning." *Journal Genetics* 4 (1914): 67–81.

Judson, Horace Freeland. *The Search for Solutions*. Baltimore, Md.: The Johns Hopkins University Press, 1987.

Kellogg, Charles. "Biology, Chemistry, and Physics Are Team Sports." *The Science Teacher* (November 1984): 36–37.

Kluger, Jeffrey. "NASA's Orbiting Dream House." *Discover* (May 1989): 68–72.

———. "Olympic Techno-Training." *Discover* (September 1988): 28.

Kusinitz, Ivan, and Morton Fine. *Your Guide to Getting Fit*. Palo Alto, Calif.: Mayfield Publishing Company, 1987.

Lapp, Diane, James Flood, and Lynne Thorpe. "Cooperative Problem Solving—Enhancing Learning in the Secondary Science Classroom." *The American Biology Teacher* 51 (1989): 112–15.

Levy, J., and T. Nagylaki. "A Model for the Genetics of Handedness." *Journal of Genetics* (1972): 117–28.

Levy, Jerre, and Jerome Levy. "Human Lateralization from Head to Foot: Sex-Related Factors." *Science* 200 (1978): 1291–92.

"Life Under Glass." *Venture* (February 1987): 57.

Lutgens, K., and K. F. Wells. *Kinesiology.* Philadelphia, Pa.: Saunders College Publishing, 1982.

McGarvey, Jack. "Be a Coach, Not a Critic." *Learning 89* (July-August 1989): 61.

McKibben, Stephen. *Personal Perspective on an Education Unit Plan.* Master's thesis, Springfield College, Springfield, Mass., 1989.

Miles, John C. "The Value of High Adventure Activities." *Leisure Activities* (April 1978): 3–11.

Moscovitch, Morris. "Differences in Neural Organization Between Individuals with Inverted and Noninverted Handwriting Postures." *Science* 205 (1979): 710–13.

Mowat, Lucia. "States Push Land Preservation." *Christian Science Monitor,* 22 January 1990,: 7.

Naismith, James. *Basketball's Origins — Critical Problem Solving In the Gilded Age.* Springfield, Mass.: Association Press, 1941.

Nickerson, Norton. *Freshwater Wetlands: Their Nature and Importance.* Boston: Tufts University, 1978.

Nowicki, Stephen, and B. R. Strickland. "A Locus of Control for Children." *Journal of Consulting and Clinical Psychology* 40 (1973): 148–54.

"An Olympian Challenge." *Cope Magazine* (August 1986): 56.

Penick, John E., and Robert E. Yager. "One Way to Fix School Science." *The Science Teacher* (January 1986): 147.

Phillips Petroleum Company. *The Search for Solutions.* Bartlesville, Okla. N.d.

Pizzini, Edward, Sandra K. Abel, and Daniel S. Shepardson. "Rethinking Thinking in the Science Classroom." *The Science Teacher* (December 1988): 22–25.

Porter, Kay, and Judy Foster. "Athletes Tell How to Get In the Win." *Los Angeles Times,* 24 November 1985, E6.

Provins, K. A. "Motorskills, Handedness, and Behavior." *Australian Journal of Psychology* 19 (1967): 137–50.

"Riddle of the Mummy with Two Skulls." *New York Times,* 22 November 1983, C2.

Rohnke, Karl. *Silver Bullets.* Hamilton, Mass.: Project Adventure Inc., 1984.

Royko, Mike. "They Were Special to the End." *Springfield Daily News,* 31 January 1986, 13.

Sackeim, H., et al. "Emotions Are Expressed More Intensely on the Left Side of the Face." *Science* 202 (1978): 434–35.

Sargent, D. A. "The Physical Test of a Man." *American Physical Education Review* 26, no. 4 (1921): 188.

Satz, Paul. "A Test of Some Models of Hemispheric Speech Organization in the Left and Right Handed." *Science* 203 (1979): 1131–33.

Scheuchenzuber, H. Joseph. *Experiments in the Mechanics of Human Movement.* Ithaca, N.Y.: Movement Publications, 1983.

Schmeck, Harold. "Left Hand May Yield Clue to Functions of Brain." *New York Times,* 1 July 1972, C1-2.

Schneider, Livingston, and John Renner. "Concrete and Formal Teaching."

Journal of Research in Science Teaching 17 (1980): 503–17.

Seisler, Jeffrey. "The Home of the Future." *Consumer's Research* (February 1987): 34–37.

Shanker, Albert. "Risk Takers Are a National Asset." *New York Times*, 2 February 1986, E7.

Silverstein, Alvin, and Virginia Silverstein. *The Left-Hander's World.* Chicago: Follett Publishing Company, 1977.

Sizer, Theodore E. *Horace's Compromise: The Dilemma of the American High School.* Boston: Houghton Mifflin Company, 1984.

Smith, Roy A. "A Teacher's View on Cooperative Learning." *Phi Delta Kappan* (May 1987): 663–66.

Smith, William. "Hard Choices in Building Design." *New Alchemy 2* (1986): 8–11.

Speece, Susan. "Teaching in the Year 2000." *The Science Teacher* (September 1986): 54-58.

Stewart, T. D. *Essential Forensic Anthropology.* Springfield, Ill.: Charles C. Thomas Publishing Company, 1979.

Sullivan, Walter. "Radiation Danger Seen in Seepage of Radon in Homes." *New York Times*, 7 October 1980, C1, 4.

Sullivan, Walter. "Solar Energy Gets a Boost from a Flurry of Designs." *New York Times*, 29 April 1986, C1, 3.

Teng, E., et al. "Handedness in a Chinese Population: Biological, Social, and Pathological Factors." *Science* 193 (1976): 1148–50.

Tierney, John. "Rubik on Rubik." *Cleveland Plain Dealer*, 11 March 1986: C1.

Travaline, Peter. "Taking a Lesson from Coaches to Teach Writing."

Massachusetts Teacher Today (17 November 1988): 198.

Trotter, Robert. "Sinister Psychology." *Science News* (5 October 1974): 220–22.

United States Consumer Product Safety Commission. *Anthropometry of Infants, Children, and Youths to Age 18 for Product Safety Design.* Washington, D.C.: U.S. Government Printing Office, 1977.

Wahl, Mark. *A Mathematical Mystery Tour: Higher-Thinking Math Tasks.* Tucson, Ariz.: Zephyr Press, 1988.

Wilford, John Noble. "Skeletons Record Burdens of Work." *New York Times,* 27 October 1987, C1, 9.

———. "A Teacher Trains for Outer Space." *New York Times Magazine,* 5 January 1986, 15-19.

Witelson, Sandra. "Sex and the Single Hemisphere: Specialization of the Right Hemisphere for Spatial Processing." *Science* 193 (1976): 425–27.

———. "Developmental Dyslexia: Two Right Hemispheres and None Left." *Science* 195 (1977): 309–11.

Yager, Robert. "STS: Thinking Over the Years." *The Science Teacher* (March 1990): 52–55.

———. "Never Playing the Game." *The Science Teacher* (September 1988): 77.

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